Oak Ridge Health Study Document Summary Form

DOCUMENT TITLE: TASK 4 - related reports or memos from the early 1960s Mostly related to Clinch River Studies (7 Documents)

DOCUMENT NUMBER OR IDENTIFIER: ERDMC # GB12

AUTHOR(S): F. L. Parker, A. G. Friend et al., Churchill et al etc.

PUBLICATION DATE: early 1960s

DATA TIME PERIOD: Start 1944 Stop 1963

LOCATION OF COPY (if one was made): ALA

CLASSIFICATION CATEGORY: UNK UNC OUO UCNI CL* *Category & Level: FRD or RD or NSI; CONF or S or TS

SITE(S) DOCUMENT ADDRESSES: K X Y S ORR MELT CLIN WOC WOL POPL EFPC PCE BEAR WATT

SOURCE/LOCATION OF DOCUMENT: 3118

DOCUMENT CATEGORY

AI [DL dr dc da] [ED ea ew es ef] EP [HO hp hr hs hw] IN IP [ST sa sw ss] TM WP

Primary category - circle once; Secondary category (optional) - circle twice. Circle only one in a bracketed group.

DATE ENTERED INTO DATABASE: BY: InMagic No.

KEYWORDS: Clinch River, Watts Bar Reservoir, Tennessee River 137 Cesium, 60 Cobalt, 106 Ruthenium, 90 Strontium, Water, Sediment, Fish

ABSTRACT:

Most of the data presented in these reports are included in Clinch River Study progress reports. There is a memo from F. L. Parker to D. M. Davis that estimates radioactive releases to Clinch River between 1944-47 (dated Dec 19, 1962). A report by A. G. Friend and coauthors (1961) considers the fate of radionuclides in the Clinch and Tennessee Rivers between 9/19-9/30 in 1960 (Progress Report 6). Water, Sediment and Fish (Bottom-feeders, gizzard shad, sight-feeders) concentrations were all recorded for this time period.

REVIEWER: Jim Knight DATE REVIEWED: 11/13/96

Note
NEW 1960
water, sed, fish
Data
+ other fish data

U.S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS
OAK RIDGE ORNL SITE OFFICE

TRANSMITTAL OF INFORMATION

The enclosed is to fulfill a request made by Chem Risk, as part of the *Oak Ridge Health Studies agreement* efforts. These documents have received the necessary reviews and may be released to the Chem Risk.

TIO Release Approval: David R Hamrin

Information enclosed: Progress report #3 subcommittee on safety evaluation, Data on fish collected in June and December, 1961 and March 1962, Clinch River study waste disposal section, Clinch river samples collected February 9-15, 1960, Estimate of Radioactivity release to the Clinch River for period, 1944-1947, Fate of radionuclides in fresh water environments, Subcommittee on water sampling and analysis Clinch River study.

Requested by: Jim Knight

Requested from: ~~Sheila Thornton~~

Approved:
Timothy W. Joseph
Program Manager
DOE ORAL Site Office

Date: August 20,1996

cc w/o enc: J. L. Weaver, 101MID, MS-6481

OFFICE MEMORANDUM

To: Linda Hill

Date: July 22, 1996

From: Sheila G. Thornton (4-9525)

Subject: Attached Documents

The attached seven documents are all ORNL documents that were located at K-25 and have been requested by ChemRisk. After these documents have been reviewed and approved for release, they should be forwarded to Mr. Jim Knight at the following address:

Mr. Jim Knight
ChemRisk
McLaren/Hart Environmental Engineering
1816 Keel Court
Lafayette, Colorado 80026

Call me if you have any questions.

Attachments 7

sgt

Linda - Jim Knight's #
(303-604-2582)
Please call when
you get these in the
mail to him. Sheila
8/20/96

20 ~~JUL~~ Aug 96 10:4

Date Received from
Sheila Thornton

29 JUL 96 10:47

ChemRisk/Shonka Research Associates, Inc., Document Request Form

(This section to be completed by subcontractor requesting document)

Jim Knight / ERDMC

Requestor — Document Center (is requested to provide the following document)

Date of request 7/17/96 Expected receipt of document ______

Document number ______ Date of document 1962

Title and author (if document is unnumbered)

Data on Fish Collected in June and December ....

Name ADC Reviewer ______

Date Sent to ADC ______

(This section to be completed by Document Center) Date(s) Cleared ______

Date request received 7/17/96

Date submitted to ~~ADC~~ ORNL 7/22/96

20 Aug 96 10:4

Date submitted to HSA Coordinator 7/18/96

(This section to be completed by HSA Coordinator)

Date submitted to CICO ORNL Document - Sent to ORNL for processing 7/22/96

Date received from CICO ______

Date submitted to ChemRisk/Shonka and DOE ______

(This section to be completed by ChemRisk/Shonka Research Associates, Inc.)

Date document received ______

Signature ______

CC: Jim Knight

To: Linda Hill - Please handle.

K. Shiels 7/22/96

(2)

ChemRisk/Shonka Research Associates, Inc., Document Request Form

(This section to be completed by subcontractor requesting document)

Jim Knight / ERDMC -
Requestor / Document Center (is requested to provide the following document)

Date of request 7/12/96 Expected receipt of document)

Document number ______ Date of document 12/19/62

Title and author (if document is unnumbered)
Memo from F L Parker
Estimate of Radioactivity Releases . . . .

Name ADC Reviewer ______
Date Sent to ADC ______
Date(s) Cleared ______

(This section to be completed by Document Center)

Date request received 7/17/96

Aus fH
20 JUL 96 10: 4

Date submitted to ~~ADC~~ ORNL 7/22/96

Date submitted to HSA Coordinator 7/18/96

(This section to be completed by HSA Coordinator)

Date submitted to CICO ORNL document - Sent to ORNL for processing 7/22/96

Date received from CICO ______

Date submitted to ChemRisk/Shonka and DOE ______

(This section to be completed by ChemRisk/Shonka Research Associates, Inc.)

Date document received ______

Signature ______

CC: Jim Knight

To: Linda Hill - Please handle.
Tx. Sheila
7/22/96

(3.)

ChemRisk/Shonka Research Associates, Inc., Document Request Form

(This section to be completed by subcontractor requesting document)

Jim Knight / ERDMC
Requestor — Document Center (is requested to provide the following document)

Date of request 7/12/96 Expected receipt of document ______

Document number ______ Date of document 12\4\63

Title and author (if document is unnumbered)
Progress Report #3
Subcommittee on Safety Evaluation

Name ADC Reviewer ______
Date Sent to ADC ______

(This section to be completed by Document Center) Date(s) Cleared ______

Date request received 7/17/96 JP

Date submitted to ~~ADC~~ ORNL 7/~~20~~/96 JP

Aug 8th
20 ~~JUL~~ 96 10: 4

Date submitted to HSA Coordinator 7/18/96

(This section to be completed by HSA Coordinator)

Date submitted to CICO ORNL Document - sent to ORNL for processing 7/22/96

Date received from CICO ______

Date submitted to ChemRisk/Shonka and DOE ______

(This section to be completed by ChemRisk/Shonka Research Associates, Inc.)

Date document received ______

Signature ______

cc: Jim Knight

To Linda Hill - Please handle. K. Hill 7/22/96

4.

ChemRisk/Shonka Research Associates, Inc., Document Request Form

(This section to be completed by subcontractor requesting document)

Jim Knight / ERDMC

Requestor — Document Center (is requested to provide the following document)

Date of request 7/17/96 — Expected receipt of document ______

Document number ______ — Date of document 1964

Title and author (if document is unnumbered)

Progress Report # 4 (FINAL)

Subcommittee on . . .

Name ADC Reviewer ______

Date Sent to ADC ______

(This section to be completed by Document Center)

Date(s) Cleared ______

Date request received 7/17/96 JP

Date submitted to ~~ADC~~ ORNL 7/22/96

Aug 8th

20 ~~JUL~~ 96 10: 4

Date submitted to HSA Coordinator 7/18/96

(This section to be completed by HSA Coordinator)

Date submitted to CICO ORNL Document – Sent to ORNL for processing 7/22/96

Date received from CICO ______

Date submitted to ChemRisk/Shonka and DOE ______

(This section to be completed by ChemRisk/Shonka Research Associates, Inc.)

Date document received ______

Signature ______

CC: Jim Knight

To: Linda Hill – Please handle. Tx Sheila 7/22/96

(5.)

ChemRisk/Shonka Research Associates, Inc., Document Request Form

(This section to be completed by subcontractor requesting document)

Jim Knight / ERDMC

Requestor   Document Center (is requested to provide the following document)

Date of request 7/17/96   Expected receipt of document ______

Document number ______   Date of document 1961

Title and author (if document is unnumbered)

Fate of Radionuclides in . . .

Sept 19-30, 1960

Name ADC Reviewer ______
Date Sent to ADC ______

(This section to be completed by Document Center)   Date(s) Cleared ______

Date request received 7/17/96 JP

Aug. 8th
20 ~~JUL~~ 96 10:4

Date submitted to ~~ADC~~ ORNL 7/22/96

Date submitted to HSA Coordinator 7/18/96

(This section to be completed by HSA Coordinator)

Date submitted to CICO ORNL Document - Sent to ORNL for processing 7/22/96

Date received from CICO ______

Date submitted to ChemRisk/Shonka and DOE ______

(This section to be completed by ChemRisk/Shonka Research Associates, Inc.)

Date document received ______

Signature ______

CC: Jim Knight

To: Linda Hill - Please handle. T.K. Sheila 7/22/96

(6.)

ChemRisk/Shonka Research Associates, Inc., Document Request Form

(This section to be completed by subcontractor requesting document)

Jim Knight / ERDMC

Requestor / Document Center (is requested to provide the following document)

Date of request 7/17/96 Expected receipt of document

Document number Date of document 1960

Title and author (if document is unnumbered)

WASTE DISPOSAL SECTION - SEDIMENT STUDIES

Name ADC Reviewer

Date Sent to ADC

(This section to be completed by Document Center) Date(s) Cleared

Date request received 7/17/96 gf

Aug 8K

20 JUL 96 10 4 Date submitted to ~~ADC~~ ORNL 7/22/96

Date submitted to HSA Coordinator 7/18/96

(This section to be completed by HSA Coordinator)

Date submitted to CICO ORNL Document - Sent to ORNL for processing 7/22/96

Date received from CICO

Date submitted to ChemRisk/Shonka and DOE

(This section to be completed by ChemRisk/Shonka Research Associates, Inc.)

Date document received

Signature

cc: Jim Knight

To: Linda Hill - Please handle. Thx. Sheila 7/22/96

7.

ChemRisk/Shonka Research Associates, Inc., Document Request Form

(This section to be completed by subcontractor requesting document)

Jim Knight / ERDMC
Requestor — Document Center (is requested to provide the following document)

Date of request 7/17/96 Expected receipt of document ________

Document number ________ Date of document 1960

Title and author (if document is unnumbered)
Report on Clinch River Studies
US PHS

Name ADC Reviewer ________
Date Sent to ADC ________

(This section to be completed by Document Center) Date(s) Cleared ________

Date request received 7/17/96 JL

Date submitted to ~~ADC~~ ORNL 7/22/96 Aug JL

20 JUL 96 10:4

Date submitted to HSA Coordinator 7/18/96

(This section to be completed by HSA Coordinator)

Date submitted to CICO ORNL Document - Sent to ORNL for processing 7/22/96

Date received from CICO ________

Date submitted to ChemRisk/Shonka and DOE ________

(This section to be completed by ChemRisk/Shonka Research Associates, Inc.)

Date document received ________

Signature ________

CC: Jim Knight

To: Linda Hill - Please handle
T. Shiels 7/22/96

X-847

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

To: D. M. Davis

Date: December 19, 1962

From: F. L. Parker

Subject: Estimate of Radioactivity Release to Clinch River for Period, 1944 through 1947

Occasionally, the question is raised of the curies of activity released to the Clinch River during the period, 1944 through 1947. Currently, we have need for such values in the Safety Analyses Subcommittee of the Clinch River Study.

Unfortunately, direct measurements of stream flow and radionuclide concentration in White Oak Creek are not available to allow calculation of release to the Clinch River during this period. Therefore, estimates of release have been made using the best data available to us (Table 1). Before such values are released, it seems advisable to have acceptance of these values by the interested sections within the Division. The remainder of this memorandum is then concerned with the sources of data and the method employed in estimating gross beta curie release to river. I would appreciate your review of the estimates and indication of their acceptability or reasons for their lack of acceptability.

The mean annual discharge from White Oak Creek was estimated on the basis of TVA flow records for Chestuee Creek at Zion Hill, Chestuee Creek above Englewood, and Little Chestuee Creek below Wilson Station (1). Estimates of flow from White Oak Creek are listed in Table 2, and include flows in the Clinch River for comparable periods.

An estimate of the concentration of gross beta activity present in fluids released at White Oak Dam (1944-1947) is based on the average value of the ratio $\frac{\text{beta activity } (\mu c/ml)}{\text{gamma radiation } (mr/hr)} = (1.3 \times 10^{-3})$ and gamma radiation

(1) Correlation analyses by the U. S. Geological Survey, Oak Ridge, Tennessee.

20 JUL 96 10: 4

measurements made during the period of interest (Table 3)(2)(3)(4). Values of mr/hr for the first 5 months of 1947 were based on the average measured values for the 6 months preceding and 7 months following this period. Parenthetical values (Table 1) of beta curies released and concentrations downstream from the confluence of White Oak Creek and the Clinch River are suggested for future reference.

The magnitude of hazard associated with the postulated release in 1946 is estimated by considering the bone as the critical organ and the average Sr^{90} content (27%) in fluids released during 1949-1958 (5). The estimated concentration of Sr^{90} at CRM 14.5 is 5×10^{-8} μc/ml, and is the same as that encountered in 1954 (the year of maximum, reasonably well known, Sr^{90} concentration). The fraction of MPC_w attained, continuous nonoccupational exposure, due to Sr^{90} in 1954 was 0.51.

Frank L. Parker
Health Physics Division

FLP:KEC:jmd

cc: H. H. Abee
W. D. Cottrell
T. H. Burnett

---

(2) H. H. Abee, unpublished data for period, 1949-1961.

(3) K. Z. Morgan and F. Western, Contamination of Water Discharged from Clinton Laboratories, MON-H-259 (8/18/47).

(4) Applied Health Physics Memorandum: CF-47-6-17; CF-47-8-441; CF-47-9-168; CF-47-10-99; CF-47-11-339; CF-47-12-397; CF-48-1-87.

(5) H. H. Abee, unpublished correspondence.

Table 1. Curies Released and Concentration of Beta Activity

Year	Beta Curies Released							
	B^- Conc. at White Oak Dam ($\times 10^{-5}$)		Flow at White Oak Dam (cfs)		Estimated B^- (curies)			
1944	5		12		550 (600)			
1945	5		10		450 (500)			
1946	6		16		870 (900)			
1947	2		12		220 (200)			
	Concentration of Beta Activity (10^{-7} μc/ml)							
	CRM 14.5		CRM 2.2		TRM 529.9		TRM 465.5	
1944	1.3	(1.0)	0.90	(0.9)	0.24	(0.2)	0.19	(0.2)
1945	1.0	(1.0)	0.72	(0.7	0.19	(0.2)	0.16	(0.2)
1946	1.9	(2.0)	1.4	(1.0)	0.33	(0.3)	0.24	(0.2)
1947	0.56	(0.6)	0.43	(0.4)	0.10	(0.1)	0.079	(0.08)

Table 2. Mean Annual Discharge (cfs)[a]

Year	White Oak Creek	CRM 14.5	CRM 2.7	TRM 529.9	TRM 465.5
1944	12	4800	6870	25,690	32,290
1945	10	4940	7020	26,490	32,270
1946	16	5150	6880	29,100	38,540
1947	12	4420	5720	24,040	31,190

[a]Values furnished by U. S. Geological Survey and Tennessee Valley Authority.

Table 3. Beta Activity Concentration and Gamma Radiation At White Oak Dam

Year	10^{-5} x μc/ml	mr/hr	10^{-3} $\frac{\mu c/ml}{mr/hr}$
1945	5	0.027	1.9
1949	4.0	0.042	0.96
1950	1.2	0.013	0.91
1951	0.73	0.027	0.27
1952	2.5	0.044	0.57
1953	2.4	0.025	0.95
1954	3.4	0.029	1.2
1955	4.4	0.022	2.0
1956	4.6	0.034	1.4
1957	2.5	0.019	1.3
1958	5.5	0.028	2.0
1959	9.2	0.044	2.1
1960	21.4	0.165	1.3

Clinch River Study
05Y/H8

[redacted]

GB#12

Fate of Radionuclides in Fresh Water Environments
Progress Report 6
Clinch and Tennessee Rivers
September 19 - 30, 1960

Albert G. Friend, Sr. Sanitary Engineer
Albert H. Story, Asst. Sanitary Engineer
C. R. Henderson, Biologist (Water Supply & Pollution Control)
Michael Howell, Jr. Asst. Sanitary Engineer
Donald B. Porcella, Zoologist, AHSO

U. S. Department of Health, Education, and Welfare
Public Health Service
Bureau of State Services
Division of Radiological Health
Robert A. Taft Sanitary Engineering Center
Cincinnati 26, Ohio

1961

CONTENTS

TABLES

TABLES (Cont'd.)

FIGURES

INTRODUCTION

This is one of a series of reports describing investigations carried out by the Radiological Health Research Activities, Division of Radiological Health, U. S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, for the Atomic Energy Commission under Contract No. AT(49-5)-1288[5]. These studies have as their purpose a definition of the fate of specific radionuclides released into fresh water environments by nuclear energy facilities.

Previous reports have described studies on this stream and other streams[1,2,3,4,5,6]. General progress reports covering overall concepts and related studies have also been published[7,8].

This report presents the results of the third study of the aquatic environment affected by the effluent from the Oak Ridge National Laboratory (ORNL). Physical features, biological conditions and sampling locations are described in earlier reports[3,5]. During this study, from September 19 to 30, 1960, samples of water, bottom sediments, and biota were collected above and below the point of the ORNL discharge into the Clinch River via White Oak Creek. The format of this report differs from previous work since all raw data has been placed in the Appendix and only the summary tables in the text. It is hoped that this will improve continuity for the reader.

Hydrology

Rainfall at Oak Ridge, Tennessee, for September 1960, as measured by the U. S. Weather Bureau is listed in Table 1A of the Appendix.

Flows in the Clinch River and related streams (Table 2A of the Appendix), are controlled by the Tennessee Valley Authority by water releases at the dams. Hydraulic, topographical, hydrologic and other descriptive factors are discussed in an earlier report[3].

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

Water

Water sampling stations (Figure 1) were located at CRM 41.5 (used for baseline); at CRM 20.8 where White Oak Creek enters the Clinch River; at Gallaher Bridge (CRM 14.6) six miles downstream; at Centers Ferry near Kingston (CRM 4.5); below Watts Bar Dam (TRM 529.9); at Henry's Ferry (TRM 517.3); and at the Chattanooga Water Treatment Plant (TRM 465.5), where influent and effluent samples were taken.

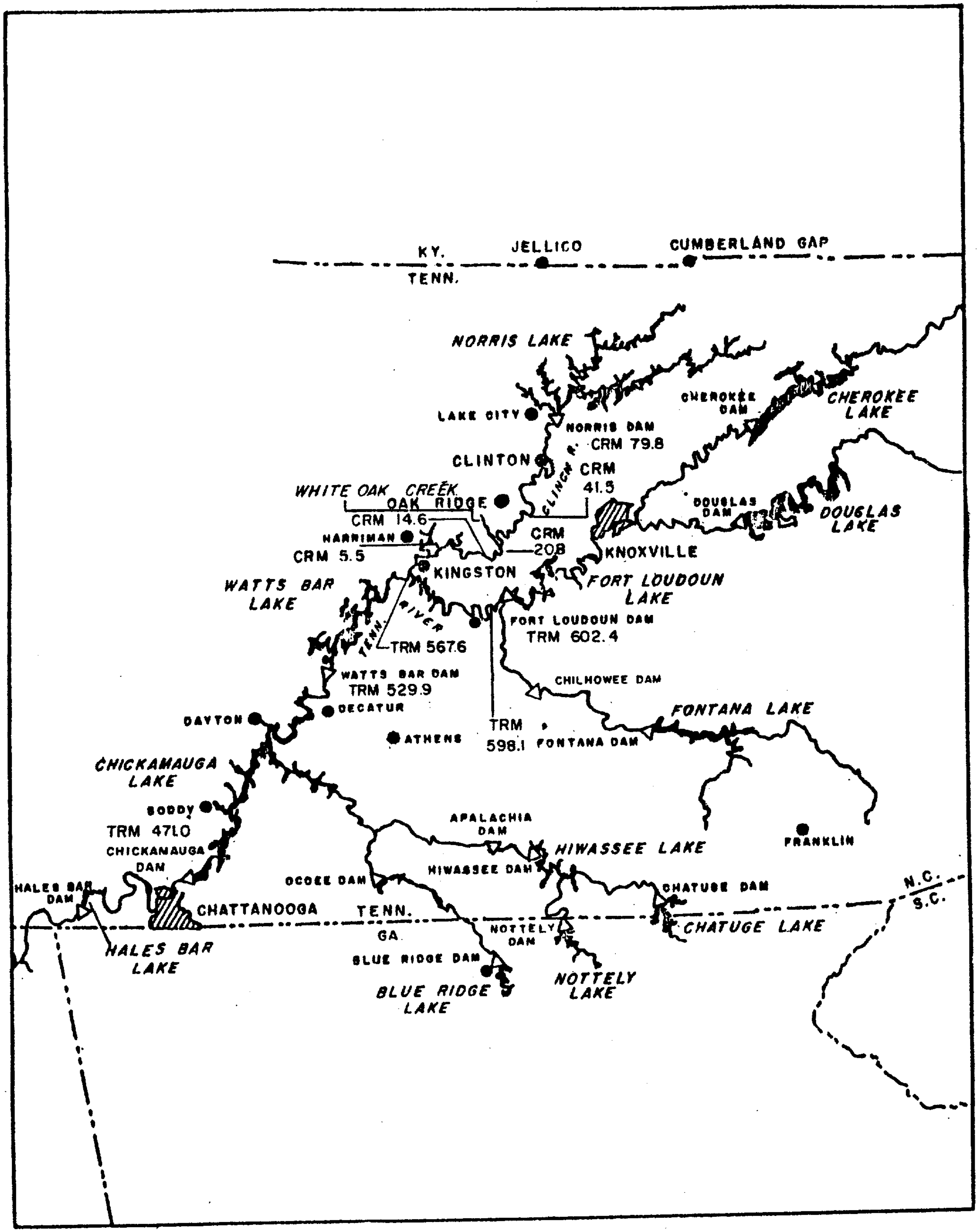
Daily, continuous water samples were collected over 8- or 9-day periods and then composited. Methods of collection and analysis have been described[4].

Bottom Sediments

The river was divided into eight, nine or ten equi-distant sampling points depending upon the width of the river, so that cross-sections of bottom sediments corresponding to the silt ranges set up by TVA could be collected. At CRM 79.8 a single sample was taken to establish baseline levels of radioactivity. Methods of sample collection, preparation and analysis have also been described[4].

Biota

Water-willow were sampled at CRM 19.6 and TRM 562.6 and clams at CRM 14.6 and TRM 517.9 to ascertain individual radionuclide concentration



CLINCH & TENNESSEE RIVERS

Figure 1

levels in organisms at these collection points.

Fish samples were collected, prepared, and analyzed as described in an earlier report[4].

RESULTS AND DISCUSSION

Water

Table 1 shows the waters at the three sampling points to be hard. Significant differences in hardness, chlorides and sulfates exist between the Clinch River, White Oak Creek, and the Tennessee River waters, What role these differences play in the fate of radionuclides in this river system is not understood at this time.

Results of radionuclide analyses of water samples are shown in Table 2. Cesium-137 and strontium-90, present above the mouth of White Oak Creek, are probably due to fallout washed into the stream by rainfall. Ruthenium-106 and strontium-90 remain in the water phase of the environment and only dilution appears to lessen their concentration. This observation confirms previous findings[5]. The levels of other radionuclides downstream were too low to measure satisfactorily due to the large and variable dilution of White Oak Creek by the Clinch River, and removal by organic material and soils; therefore, no conclusions are drawn concerning them.

Bottom Sediments

Cross-sectional bottom-sediment sample data are shown in Table 3A of the Appendix. Column 2 shows the position of the sample with reference to the right hand (north) shore of the river while facing downstream. Samples were taken at equally spaced intervals along the

TABLE 1.

Water Quality*

September, 1960

Test	White Oak Creek	CRM 14.6	TRM 517.3
pH	7.7	7.9	7.8
	Expressed in parts per million		
Alkalinity ($CaCO_3$)	127.0	106.0	54.0
Hardness ($CaCO_3$)	148.0	130.0	88.0
Cl^-	6.0	3.0	22.5
SO_4^{--}	30.0	18.0	12.0
Ca^{++}	34.0	37.6	24.0
Mg^{++}	15.0	8.7	7.0
PO_4^{---}	Trace	Trace	Trace
Total Dissolved Solids	210.0	137.0	130.0

* Basic Water Quality Network Laboratory, R. C. Kroner, USPHS, Cincinnati, Ohio.

TABLE 2.

Radionuclide Concentrations in Composite Water Samples

Collected from Stations on the Clinch and Tennessee Rivers

September, 1960

Collection point	Initial volume, liters	Activity in total solids, μμc/liter				
		Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}
CRM 41.5	62.1	---*	370	---	---	2.6 ± 0.2
Mouth of White Oak Creek	32.0**	460,000	14,000	2,000	13,000	[illegible]0 ± 95
CRM 14.6	60.6**	100	5	---	5	3.0 ± 0.2
CRM 4.5	60.2	170	---	5	5	7.1 ± 0.2
TRM 529.9	47.6	10	---	---	---	12.0 ± 0.7
TRM 517.3	48.2**	---	---	---	---	2.4 ± 0.2
TRM 465.5	65.1	10	---	---	---	1.2 ± 0.1
TRM 465.5	64.5	5	---	---	---	1.04 ± 0.2

* Values below limits of detectability.

** Water quality data performed on part of this sample.

nine cross-sections indicated in column 1.

Some general trends are observable in the variation in average (cross-sectional) activities for the specific radionuclides (Table 3). These trends may be explained on the basis of stream hydraulics and the mechanisms of radionuclide uptake. The low activities at CRM 19.2 are believed due to the incomplete mixing of the discharged wastes and the waters of the Clinch River (and their suspended load) and to the nature of the deposition of sediments. At this point, the river is still free flowing and any deposited sediments are fairly coarse textured (large particle sizes). These are carried along the bottom of the stream rather than in suspension. Thus, they may not come in close contact with the radioactive waste waters. Some mixing and deposition of activity does occur, however, especially on the north bank (sample no. 1, Table 3A). This high activity also may be due to settling of sediments that have been carried out of White Oak Creek.

Before the waters reach CRM 11.9, complete mixing has occurred. Here the river enters the quiet waters of Watts Bar Reservoir and rapid deposition of the suspended material takes place. Peak deposition of all radionuclides studied occurs here. Beyond this point, a general decrease in the activity levels of the bottom sediments is observed. The large dilution occurring on entrance of the Clinch River into the Tennessee River is reflected precisely in the activities of the bottom sediments. The relatively higher activities at TRM 538.6, and lower levels at 537.7 are explainable on the basis of stream hydraulics. At TRM 537.7 a considerable narrowing or constriction of the river occurs,

TABLE 3.

Average Radionuclide Concentrations for Cross-sections of the Bottom Sediments, Clinch and Tennessee Rivers

September, 1960

Sampling point	No. of transverse divisions	Activity, μμc/kg (oven dry weight) Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}
CRM 19.2	9	27,000	59,000	1,900	6,500	1,500
CRM 11.9	8	130,000	160,000	5,800	18,000	3,800
CRM 7.6	9	100,000	140,000	730	16,000	3,500
CRM 1.3	9	130,000	120,000	2,100	15,000	1,600
TRM 562.3	10	26,000	23,000	340	3,400	450
TRM 557.2	10	24,000	20,000	700	3,100	640
TRM 538.6	10	34,000	25,000	2,100	4,100	600
TRM 537.7	10	12,000	6,000	290	1,500	360
TRM 496.6	10	33,000	11,000	600	2,200	460

thus greatly increasing stream velocity and changing the nature of the sediments deposited in this reach of the stream. Studies by the TVA show that only one-third as much sediment has been deposited at this point as at other stations. The sediments are probably composed of coarser and less active material. As would be expected, the backwater effect above the constriction at TRM 537.7 permits deposition of finer particles and there is an increase in activity levels. Increases in ruthenium-106 and zirconium-95-niobium-95 at CRM 1.3 are probably due to physical or chemical changes in the waters at this point and indicate a similar mode of deposition for these radionuclides.

The uniform decrease in cesium-137, cobalt-60, and strontium-90 below CRM 11.9 (with the exception noted at TRM 538-537) is explained by other factors operative in the system. Part of the decrease of all activities downstream is due to dilution of the radioactive sediment and water by water from uncontaminated tributaries. In addition, a general decrease occurs due to a non-reversible removal of cesium-137, cobalt-60 and strontium-90 by adsorption on suspended materials with subsequent settling. The relative non-reversibility of the sorption mechanisms allows these specific radionuclides to concentrate in the upper reaches of the Clinch River, and to decrease in the lower Tennessee. Cesium-137 is believed to be fixed in the illitic clay minerals by a mechanism described by Tamura[10]; cobalt-60 is believed to be chelated by organic materials, and strontium-90 is held by calcium carbonates and phosphates. The latter mechanisms are only slowly reversible in this system.

Table 4 shows the percent of the total activity represented by each radionuclide. While ruthenium-106 concentration increases, cesium-137 in the sediments decreases with distance downstream from White Oak Creek; this confirms the relationship found in a previous study[5].

None of the variations in cross-sectional activities is explainable on the basis of present data. Measurement of depth, stream velocity, and particle size distributions in conjunction with activity levels should clarify this situation in the future, however.

Miscellaneous Biota

Radionuclide concentrations in vascular aquatic vegetation (water willow), as shown in Table 5, indicate that these plants concentrate radionuclides from the water about 2000-fold (ratio activity/kg live weight to activity/liter of water) at CRM 14.6 (refer to Table 5 and Table 2). Downstream samples have activity levels which are one-third to one-twelfth less. This decrease is only partially attributed to dilution.

Variations in the radionuclide concentrations in clams from different sampling stations likewise do not appear to be due to dilution factors (Table 6). Measurements of stable strontium and age of the clams offer a correction factor, however, that should correlate with dilution*.

Fish

Data for fish are given in Tables 4A, 5A, and 6A of the Appendix. The fish have been separated into groups according to feeding types, i.e.,

* Personal communication, D. J. Nelson, Oak Ridge National Laboratories, Health Physics Division, (1961).

TABLE 4.

Percent of Average Total Activity Represented by each Radionuclide at Various Cross-sections on the Clinch and Tennessee Rivers - Sept., 1960

River & Mile		Average total activity, $\mu\mu c/kg$ dry weight	Percent of Total Activity				
			Ru^{106}	Cs^{137}	$Zr^{95}-Nb^{95}$	Co^{60}	Sr^{90}
CRM	19.2	96,000	28	61	1.9	6.8	1.5
	11.9	320,000	41	50	1.8	5.6	1.2
	7.6	260,000	38	54	0.3	6.2	1.4
	1.3	270,000	48	44	0.8	5.5	0.6
TRM	562.3	53,000	49	43	0.6	6.4	0.8
	557.2	48,000	50	42	1.5	6.5	1.3
	538.6	66,000	52	38	3.2	6.2	0.9
	537.7	20,000	60	30	1.5	7.5	1.8
	496.6	47,000	70	23	1.3	4.7	1.0

TABLE 5.

Radionuclide Concentrations in Water Willow

Collected in the Clinch and Tennessee Rivers

September, 1960

Collection point	Activity, μμc/kg (live weight)				
	Ru^{106}	Cs^{137}	$Zr^{95}-Nb^{95}$	Co^{60}	Sr^{90}
CRM 19.6	201,000	75,000	2,250	23,000	16,000 ± 270
TRM 562.6	24,000	4,400	680	1,800	1,250 ± 20

TABLE 6.

Radionuclide Concentrations in Clams Collected

on the Clinch and Tennessee Rivers

September, 1960

Collection point	No.	Live weight grams	Fraction	Activity, μμc/kg (live weight)				
				Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}
CRM 14.6	2	111.4	Flesh	22,000	2,700	---*	1,800	17,000 ± 1250
			Shell	5,500	3.300	---	1,900	40,000 ± 950
TRM 517.9	10	836.3	Flesh	8,900	370	130	290	410 ± 20
			Shell	1,000	65	90	35	1,000 ± 290

* Indicates values below level of detectability.

bottom-feeders, plankton-feeders and sight-feeders[4].

The activity in bottom-feeding fish is accumulated from the water (since activity levels in the bottom-feeder food chain reflect water concentrations, the activity levels in fish can be considered to be a result of concentrations in water)[5]. Much of the activity in whole fish with bottom-feeding habits, however, (Table 7) is from the mud ingested along with the food and accumulated in the stomach and intestine. Activity levels in the flesh and bone of these fish indicate that actual incorporation of radionuclides from mud does not occur; this confirms a previous finding[5].

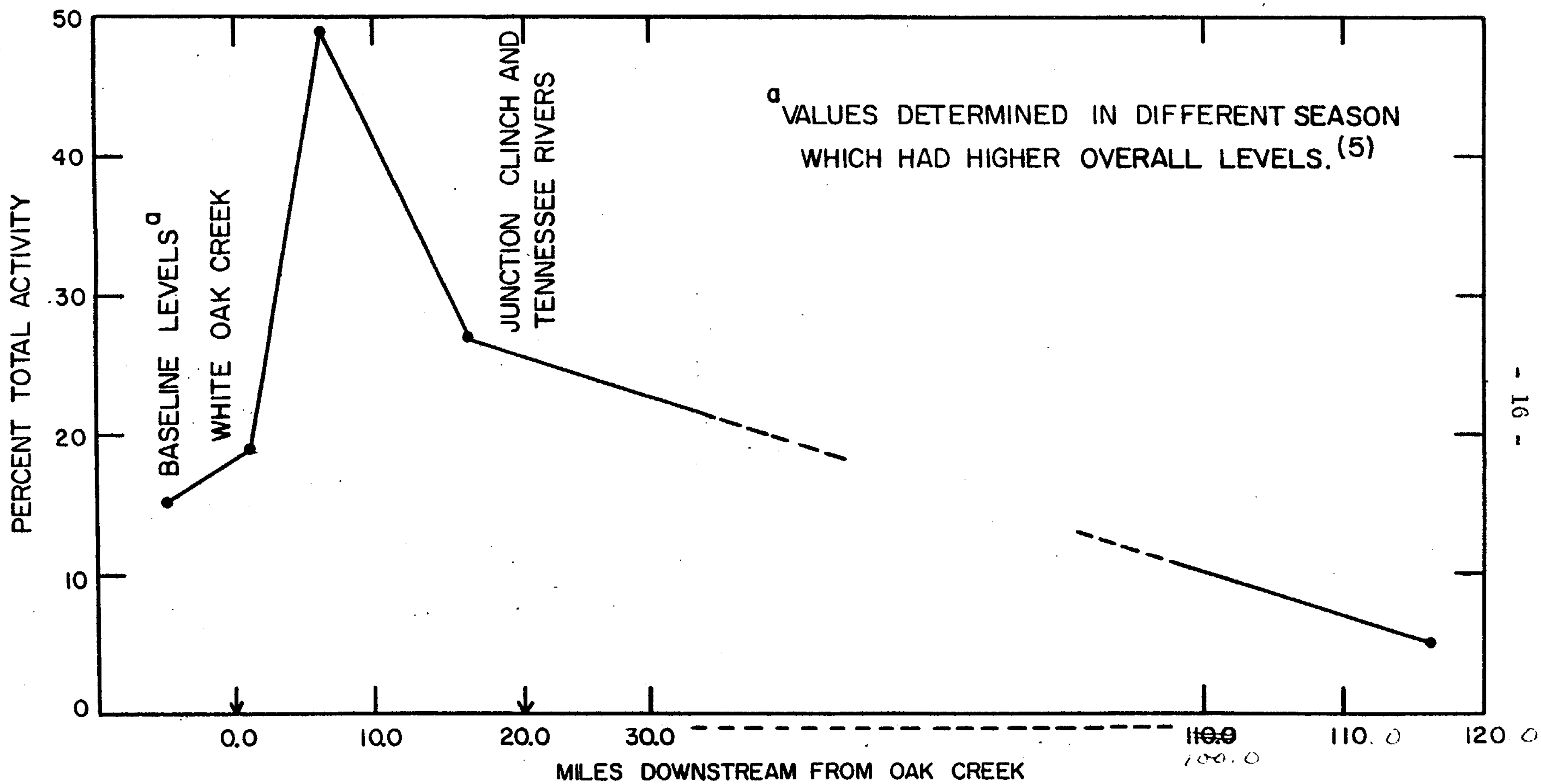
The average percentages of the total activity in bottom-feeding fish are shown in Figure 2. Activity levels in the whole fish should indicate where the fish were feeding; e.g., high values indicate feeding in muds of high activity. The values found in the sediments at CRM 4.5 (Table 3), however, although approximately the same as those at CRM 14.6, do not correlate with the levels in the fish at those two points. The high levels of activity at CRM 14.6 can be explained by assuming that activity levels in the food sources of the fish reach a peak near CRM 14.6. Upstream from this area mixing is not complete while further downstream activity levels in the water are lower; thus, in both cases, less activity is accumulated in the food.

It is probable that the activity levels of the food, the feeding habits and age of the fish, and other parameters must be considered to explain the true fate of radionuclides among fish collected from widely separated sampling points.

TABLE 7.

Average Radionuclide Concentrations in the Flesh, Bone, Whole Fish and Viscera of Bottom Feeding Fish, Clinch and Tennessee Rivers, September, 1960

River mile	No. of fish	Activity, $\mu\mu c/kg$ (live weight) Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}	Total activity	Percent of total activity
				Flesh				
19.6	4	5	560	70	80	1,300	2,015	27
14.6	9	60	860	60	110	1,800	2,890	39
4.5	3	65	490	95	95	1,500	2,245	30
471.0	2	35	30	15	40	180	300	4
				Bone				
19.6		65	240	45	260	3,900	4,510	19
14.6		160	300	95	260	4,200	5,015	22
4.5		160	300	150	75	12,000	12,685	54
471.0		175	35	10	35	880	1,135	5
				Whole fish				
19.6		160	660	80	170	not analyzed for Sr^{90}	1,070	19
14.6		890	1,500	85	270		2,745	49
4.5		500	750	130	140		1,520	27
471.0		140	45	25	45		255	5
				Viscera				
19.6		490	1,100	120	230	not analyzed for Sr^{90}	1,940	16
14.6		2,500	3,200	95	400		6,195	51
4.5		1,500	1,500	180	260		3,440	28
471.0		400	65	65	75		605	5



AVERAGE TOTAL ACTIVITY IN BOTTOM-FEEDING FISH

FIGURE 2

Table 7 lists average concentrations of the individual radionuclides in bottom-feeding fish. The relationship between the activities in the flesh and the bone reflects the metabolism of the two fractions. Flesh more accurately reflects levels in the foods because of its higher rate of metabolism; thus, flesh achieves an equilibrium between the rate of uptake versus excretion sooner than bone. In an exposure, flesh would rapidly accumulate a large amount of activity, whereas levels in bone might not show striking differences.

Because there is not much exchange of strontium from bone, large amounts of strontium-90 are accumulated; if exposure were constant, this would be explained by growth rates. Cesium-137 which does not become a part of cell structures is not accumulated by bone; however, it represents the largest percentage of the activity in muscular tissue, which indicates participation in muscle cell metabolism.

Data on ruthenium-106, zirconium-95-niobium-95 and cobalt-60 do not present a clear picture of distribution within the tissues. Because the levels of these radionuclides in the tissues are so low, they are less important than cesium-137 and strontium-90. These low levels probably are due to the unavailability of the radionuclides in the food chain or to the active metabolic discrimination by the organism. The accumulation of ruthenium-106, zirconium-95-niobium-95, and cobalt-60 to a high degree by water willow (Table 5) may be largely due to foliar deposition of suspended particles on the plant surfaces; thus, these radionuclides may not be readily available for incorporation into flesh or bone through the floral segment of the food chain.

A possible correlation between sight-feeding and plankton-feeding fish was observed. These plankton-feeders consist solely of gizzard shad. The food of sight-feeding fish is generally juvenile fish, which also feed almost exclusively upon plankton. The correlation appears in the similarity of differences between levels of activity for each of these feeding types at each station (Fig. 3).

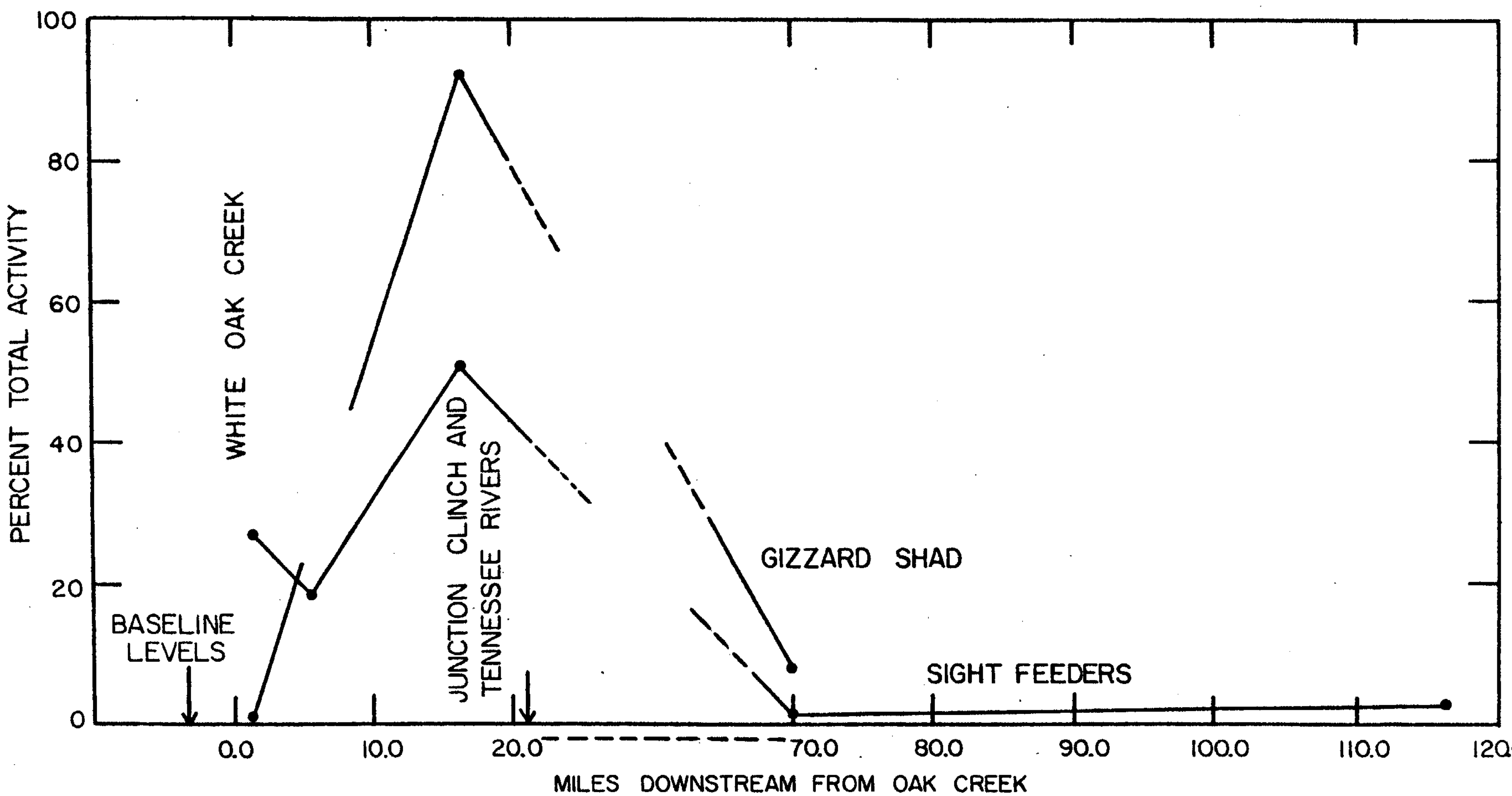
At CRM 19.6, the relatively low activity levels in plankton-feeders correlate well with the observation that most of the activity in the water at that station is not associated with the suspended solids (which includes the plankton) but with the dissolved solids fraction[5]. Further downstream this association is reversed and, correspondingly, activity levels in the gizzard shad are higher (Table 5A).

The high levels in the bone of some of the sight-feeding fish (Table 6A of the Appendix) indicate the long biological half-life of radionuclides that accumulate in the bone.

CONCLUSIONS

Levels of activity in water, except in White Oak Creek, are generally too low for specific conclusions to be drawn; the water chemistry of the different streams differs significantly, however. In future studies, water chemistry may be correlated with rates of transfer between dissolved and solid phases.

Activity levels in mud apparently can be correlated with stream hydraulics. The activity levels in the sediments are associated with the size of the particles present in the stream bed. The number of small-sized and low-density particles with which the greatest amount of activity



AVERAGE TOTAL ACTIVITY IN GIZZARD SHAD AND SIGHT-FEEDING FISH

FIGURE 3

per unit weight is associated, is directly affected by stream velocity. This was illustrated in the comparison of stream cross-sectional area and silt depth increase at TRM 538.8 and 537.7.

The distribution of individual radionuclides is different from that of the total activity levels. Cesium-137 is rapidly transferred to the bottom sediments. The highest levels of cobalt-60 are found at highest concentrations of organic material.

The biota indicates only activity levels and some basic ecological relationships. Better definition of exposure times, feeding habits, and fractionation methods of the entire fish will aid in making definite conclusions about the fate of specific radionuclides. Certain steps in the food chains of bottom-feeders, plankton-feeders and sight-feeders, have been indicated but are not conclusive at this time.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to the personnel of the Health Physics Section at Oak Ridge National Laboratory, Mr. E. G. Struxness, Chief, for their cooperation in carrying out the sampling program in the field.

Strontium-90 analyses were made by Mr. Jasper Kearney, Radionuclide Analysis Unit - Chemistry, Mr. Paul Hallbach, Chief, and instrumental gamma pulse height analyses by Mr. Walden Crocker and Mr. Jack Bowen, of the Radionuclide Analysis Unit - Physics, Mr. Byron Branson, Chief. The authors wish to acknowledge their help in making these analyses.

Three persons from the Cooperative Studies Unit deserve mention in these acknowledgments: Miss Gretchen Wehrmeyer, Mr. Eugene Pinkston, and Mrs. Helen Logan. The authors wish to extend them the credit they deserve for their diligent work.

REFERENCES

1. Friend, A. G., Story, A. H., Howell, M., and Henderson, C. R. "Fate of Radionuclides in Fresh Water Environments", Progress Report No. 1, Mohawk River; September 16 - October 4, 1959. Robert A. Taft Sanitary Engineering Center, Division of Radiological Health, U. S. Public Health Service, Cincinnati, Ohio. 103 pp. (Mimeo) (1960).

2. Friend, A. G., Story, A. H., Howell, M., and Henderson, C. R. "Distribution of Specific Radionuclides in the Hydrosphere below KAPL", presented at the Health Physics Society Annual Meeting in Boston, Massachusetts, June 30 - July 1 and 2, 1960. Robert A. Taft Sanitary Engineering Center, Division of Radiological Health, U. S. Public Health Service, Cincinnati, Ohio. 76 pp. (Mimeo) (1960).

3. Friend, A. G., Story, A. H., Howell, M., and Henderson, C. R. "Fate of Radionuclides in Fresh Water Environments", Progress Report No. 2, Clinch and Tennessee Rivers; February 9 - 15, 1960. Robert A. Taft Sanitary Engineering Center, Division of Radiological Health, U. S. Public Health Service, Cincinnati, Ohio. 61 pp. (Mimeo) (1960).

4. Friend, A. G., Story, A. H., Howell, M., and Henderson, C. R. "Fate of Radionuclides in Fresh Water Environments", Progress Report No. 3, Mohawk River; June 15 - 23, 1960. Robert A. Taft Sanitary Engineering Center, Division of Radiological Health, U. S. Public Health Service, Cincinnati, Ohio. 50 pp. (1961).

5. Friend, A. G., Story, A. H., Howell, M., and Henderson, C. R. "Fate of Radionuclides in Fresh Water Environments", Progress Report No. 5, Clinch and Tennessee Rivers; May 15 - 30, 1960. Robert A. Taft Sanitary Engineering Center, Division of Radiological Health, U. S. Public Health Service, Cincinnati, Ohio. 39 pp. (1961).

6. Friend, A. G., Diephaus, E. A., Story, A. H., and Henderson, C. R. "Fate of Radionuclides in Fresh Water Environments", Progress Report No. 4, Lower Three Runs and Savannah River, August 14 - 25, 1960. Robert A. Taft Sanitary Engineering Center, Division of Radiological Health, U. S. Public Health Service, Cincinnati, Ohio. (In Press).

7. Straub, Conrad P., and Goldin, Abraham S. "Fate of Radioactive Contaminants in Water". Progress Report No. 1 (For the Period April 7, 1957 to May 1, 1958). Technical Report R59-2, Robert A. Taft Sanitary Engineering Center, Division of Radiological Health, U. S. Public Health Service, Cincinnati, Ohio. 52 pp. (1959).

8. Straub, Conrad P., Goldin, Abraham S., Hagee, G. Richard and Friend, Albert G. "Fate of Radioactive Contaminants in Water." Progress Report No. 2 (For the Period May 1, 1958 to June 30, 1959). Technical Report R60-2, Robert A. Taft Sanitary Engineering Center, Division of Radiological Health, U. S. Public Health Service, Cincinnati, Ohio. 33 pp. (1960).

9. Bailey, Reeve M., Chairman, Lachow, Ernest A., Lindsey, C. C., Robins, C. Richard, Roedel, Phil M., Scott, W. B., and Woods, Loren P. "A List of Common and Scientific Names of Fishes from the United States and Canada". Second Edition: American Fisheries Society, Special Publication No. 2. Ann Arbor, Michigan. 102 pp. (1960).

10. Tamura, T., and Jacobs, D. G. "Structural Implications in Cesium Sorption". Health Physics, Vol. 2, pp. 391-398. (1960).

TABLE 1A

Rainfall at Oak Ridge, Tennessee*

Sept., 1960	Inches
10	1.47
11	0.15
16	0.83
17	0.50
26	0.01
28	0.38
29	0.13
Total	3.62

* Data Courtesy, U. S. Weather Bureau.

TABLE 2A

Flow Rates in Cubic Feet Per Second at Gauging Stations

on the Clinch and Tennessee Rivers*

Date, Sept., 1960	Gauging Stations				
	Norris CRM 79.8	Watts Bar TRM 529.9	Chickamauga TRM 471.0	Ft. Loudon TRM 602.3	Chilhowee LTRM 33.6
19	4,605	31,210	40,100	9,400	7,658
20	4,686	38,100	39,900	18,500	8,152
21	4,435	28,500	40,100	14,700	8,076
22	4,598	26,000	41,000	17,500	6,523
23	5,134	31,200	42,200	20,100	6,284
24	4,559	40,400	41,800	20,500	3,377
25	3,681	31,200	19,100	14,900	3,221
26	3,693	30,900	33,800	20,700	6,156
27	3,520	30,300	35,200	25,600	5,221
28	3,897	29,000	36,500	23,300	7,543
29	4,108	29,800	40,400	19,700	4,762
30	3,075	28,600	37,400	19,000	3,201
Average	4,170	31,270	37,290	18,680	5,850

* Data Courtesy, Tennessee Valley Authority.

TABLE 3A

Radionuclide Concentrations in Bottom Sediment Samples

Clinch and Tennessee Rivers - September, 1960.

Sampling point (1)	Cross-sectional sample No. (2)	Activity, μμc/kg (oven weight) Ru^{106} (3)	Cs^{137} (4)	Zr^{95}-Nb^{95} (5)	Co^{60} (6)	Sr^{90} (7)
CRM 79.8	***	3,800	1,300	480	600	N. D.**
CRM 19.2	1	83,000	260,000	8,400	24,000	370 ± 180
	2	31,000	30,000	---*	7,400	390 ± 85
	3	35,000	31,000	1,300	6,600	540 ± 180
	4	27,000	34,000	---	4,400	2600 ± 250
	5	28,000	51,000	3,900	5,300	1085 ± 270
	6	15,000	17,000	1,400	2,200	560 ± 130
	7	12,000	12,000	240	1,200	1225 ± 190
	8	6,000	88,000	830	6,000	1150 ± 125
	9	9,000	9,000	1,000	1,400	5365 ± 190
CRM 11.9	1	36,000	140,000	1,900	14,000	4830 ± 190
	2	130,000	140,000	1,100	16,000	4090 ± 90
	3	140,000	240,000	8,800	26,000	6190 ± 280
	4	120,000	140,000	---	15,000	3750 ± 315
	5	120,000	110,000	---	12,000	2270 ± 180
	6	100,000	120,000	---	12,000	2550 ± 150
	7	120,000	120,000	790	12,000	1890 ± 225
	8	260,000	300,000	34,000	34,000	4750 ± 190

TABLE 3A (Cont'd.)

Radionuclide Concentrations in Bottom Sediment Samples

Clinch and Tennessee Rivers - September, 1960.

Sampling point (1)	Cross-sectional sample No. (2)	Activity, μμc/kg (oven weight) Ru^{106} (3)	Cs^{137} (4)	$Zr^{95}-Nb^{95}$ (5)	Co^{60} (6)	Sr^{90} (7)
CRM 7.6	1	72,000	79,000	---	9,100	1270 ± 80
	2	140,000	140,000	4,000	17,000	1680 ± 140
	3	100,000	110,000	2,600	14,000	4960 ± 1680
	4	84,000	170,000	---	17,000	3730 ± 190
	5	190,000	170,000	---	21,000	6640 ± 275
	6	110,000	110,000	---	13,000	6160 ± 320
	7	55,000	160,000	---	23,000	2900 ± 185
	8	56,000	100,000	---	14,000	3500 ± 370
	9	110,000	110,000	---	16,000	1060 ± 95
CRM 1.3	1	210,000	190,000	---	25,000	3690 ± 275
	2	240,000	210,000	---	25,000	1470 ± 140
	3	140,000	110,000	4,600	14,000	365 ± 55
	4	85,000	110,000	---	11,000	2900 ± 220
	5	170,000	170,000	14,000	21,000	1185 ± 80
	6	120,000	92,000	---	11,000	2300 ± 220
	7	90,000	77,000	---	9,900	540 ± 80
	8	81,000	80,000	---	9,800	830 ± 170
	9	41,000	39,000	---	6,100	660 ± 95

TABLE 3A (Cont'd.)

Radionuclide Concentrations in Bottom Sediment Samples

Clinch and Tennessee Rivers - September, 1960.

Sampling point (1)	Cross-sectional sample No. (2)	Activity, μμc/kg (oven weight) Ru^{106} (3)	Cs^{137} (4)	Zr^{95}-Nb^{95} (5)	Co^{60} (6)	Sr^{90} (7)
TRM 562.3	1	14,000	19,000	1,100	3,000	560 ± 190
	2	29,000	29,000	790	3,900	455 ± 65
	3	29,000	30,000	---	3,900	470 ± 100
	4	30,000	25,000	160	3,700	360 ± 60
	5	13,000	4,600	280	1,600	370 ± 60
	6	28,000	20,000	---	3,000	340 ± 170
	7	15,000	10,000	660	2,400	190 ± 40
	8	31,000	27,000	---	3,600	470 ± 95
	9	39,000	33,000	370	4,800	550 ± 230
	10	33,000	33,000	---	4,200	550 ± 230
TRM 557.2	1	23,000	19,000	840	2,900	630 ± 180
	2	11,000	13,000	380	2,300	170 ± 60
	3	23,000	23,000	710	3,100	1270 ± 150
	4	27,000	25,000	1,100	3,500	715 ± 180
	5	28,000	23,000	---	3,000	1230 ± 170
	6	14,000	17,000	790	3,300	190 ± 50
	7	25,000	18,000	---	2,800	640 ± 180
	8	54,000	44,000	2,900	6,600	850 ± 140
	9	18,000	11,000	200	2,200	280 ± 30
	10	12,000	10,000	70	1,500	465 ± 90

TABLE 3A (Cont'd.)

Radionuclide Concentrations in Bottom Sediment Samples

Clinch and Tennessee Rivers - September, 1960.

Sampling point (1)	Cross-sectional sample No. (2)	Activity, μμc/kg (oven weight)				
		Ru^{106} (3)	Cs^{137} (4)	Zr^{95}-Nb^{95} (5)	Co^{60} (6)	Sr^{90} (7)
TRM 538.6	1	96,000	92,000	4,600	13,000	895 ± 90
	2	46,000	32,000	1,000	5,000	810 ± 140
	3	19,000	12,000	---	2,600	190 ± 95
	4	47,000	44,000	12,800	6,100	550 ± 90
	5	30,000	12,000	540	2,700	190 ± 70
	6	14,000	3,600	450	1,900	560 ± 85
	7	26,000	14,000	580	2,500	280 ± 95
	8	22,000	13,000	450	2,500	1280 ± 60
	9	20,000	14,000	170	2,300	490 ± 90
	10	21,000	13,000	1,000	2,400	730 ± 90
TRM 537.7	1	11,000	4,100	380	1,300	190 ± 55
	2	21,000	6,900	700	1,800	285 ± 75
	3	11,000	3,600	300	1,500	95 ± 10
	4	6,300	1,600	170	1,000	195 ± 100
	5	8,600	3,100	270	1,100	100 ± 20
	6	5,200	2,000	360	1,100	100 ± 60
	7	4,500	1,600	220	650	870 ± 190
	8	8,900	3,800	250	1,300	195 ± 60
	9	26,000	16,000	210	2,800	730 ± 260
	10	17,000	17,000	---	2,500	810 ± 180

TABLE 3A (Cont'd.)

Radionuclide Concentrations in Bottom Sediment Samples

Clinch and Tennessee Rivers - September, 1960.

Sampling point (1)	Cross-sectional sample No. (2)	Activity, μμc/kg (oven weight) Ru^{106} (3)	Cs^{137} (4)	$Zr^{95}-Nb^{95}$ (5)	Co^{60} (6)	Sr^{90} (7)
TRM 496.6	1	15,000	4,900	190	1,200	190 ± 40
	2	9,200	2,700	360	1,100	190 ± 65
	3	49,000	12,000	860	2,800	1230 ± 340
	4	75,000	21,000	360	3,900	275 ± 65
	5	44,000	11,000	180	2,300	560 ± 120
	6	32,000	8,200	690	1,900	390 ± 90
	7	35,000	11,000	290	2,500	570 ± 190
	8	26,000	6,700	80	1,300	690 ± 100
	9	28,000	34,000	2,600	4,600	190 ± 75
	10	13,000	1,800	370	630	280 ± 95

* Values below limits of detectability.

** Not determined.

*** Baseline sample, no cross-section taken.

TABLE 4A

Radionuclide Concentrations in Bottom-feeding Fish

Collected on the Clinch and Tennessee Rivers, September, 1960.

Species(9)	Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight) Ru^{106}	Cs^{137}	$Zr^{95}-Nb^{95}$	Co^{60}	Sr^{90}**
Carp sucker	19.6 CRM	1	1134	Flesh	10	160	25	30	120 $\pm$ 5
				Bone	110	50	---*	50	1400 $\pm$ 90
				Viscera	440	1,000	130	110	
				Whole fish	170	420	60	60	
Carp sucker	19.6 CRM	1	1389	Flesh	---	640	60	120	3200 $\pm$ 70
				Bone	---	270	180	360	4800 $\pm$ 20
				Viscera	270	1,000	95	330	
				Whole fish	70	650	95	230	
Carp sucker	19.6 CRM	1		Flesh	---	960	100	100	1200 $\pm$ 25
				Bone	160	290	---	300	8000 $\pm$ 220
				Viscera	540	860	120	160	
				Whole fish	170	790	85	160	
Quillback carpsucker	19.6 CRM	1	1276	Flesh	15	520	100	60	840 $\pm$ 40
				Bone	---	300	---	270	1250 $\pm$ 20
				Viscera	760	1,400	140	370	
				Whole fish	210	690	85	200	
Quillback carpsucker	14.6 CRM	1	1219	Flesh	---	260	60	80	1300 $\pm$ 100
				Bone	90	110	190	150	3800 $\pm$ 130
				Viscera	1,900	2,700	120	490	
				Whole fish	540	900	200		

TABLE 4A (Cont'd.)

Radionuclide Concentrations in Bottom-feeding Fish

Collected on the Clinch and Tennessee Rivers, September, 1960.

Species (9)	Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight) Ru^{106}	Cs^{137}	$Zr^{95}-Nb^{95}$	Co^{60}	Sr^{90}**
River carp sucker	14.6 CRM	1	1729	Flesh	50	1,300	100	60	
				Bone	420	520	140	360	1500 ± 30
				Viscera	6,000	8,000	120	970	
				Whole fish	1,700	2,900	120	380	
River carp sucker	14.6 CRM	1	1219	Flesh	160	570	40	180	80 ± 5
				Bone	150	150	---	320	3100 ± 90
				Viscera	3,400	4,000	100	680	
				Whole fish	1,000	1,400	50	380	
River carp sucker	14.6 CRM	1	1304	Flesh	---	1,700	80	120	640 ± 25
				Bone	---	320	140	250	10000 ± 320
				Viscera	1,600	2,300	20	380	
				Whole fish	520	1,600	75	240	
River carp sucker	14.6 CRM	1	1503	Flesh	80	890	65	110	470 ± 15
				Bone	300	310	100	170	2700 ± 40
				Viscera	2,600	2,500	120	350	
				Whole fish	1,000	1,300	90	210	
River carp sucker	14.6 CRM	1	1474	Flesh	100	820	10	60	
				Bone	340	390	10	140	2500 ± 320
				Viscera	2,200	3,300	110	360	
				Whole fish	820	1,500	40	180	

TABLE 4A (Cont'd.)

Radionuclide Concentrations in Bottom-feeding Fish

Collected on the Clinch and Tennessee Rivers, September, 1960.

Species(9)	Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight) Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90**}
Carp	14.6 CRM	3	1588	Flesh	40	460	80	140	6700 ± 105
				Bone	100	190	120	410	5700 ± 65
				Viscera	1,100	1,400	100	320	
				Whole fish	420	730	95	260	
Redhorse sucker	4.5 CRM	1	1729	Flesh	85	420	75	75	1800 ± 85
				Bone	150	350	---	160	16000 ± 160
				Viscera	2,600	2,500	260	400	
				Whole fish	850	1,000	120	180	
Redhorse sucker	4.5 CRM	1	2041	Flesh	55	520	110	110	1700 ± 50
				Bone	220	480	480	---	18000 ± 430
				Viscera	1,400	1,400	180	250	
				Whole fish	510	810	160	150	
Redhorse sucker	4.5 CRM	1	1786	Flesh	60	530	95	95	1000 ± 45
				Bone	120	110	100	40	3200 ± 160
				Viscera	340	430	100	130	
				Whole fish	140	450	95	100	
Carp	471.0	1	652	Flesh	25	35	10	25	200 ± 10
				Bone	170	60	5	65	1400 ± 90
				Viscera	230	75	20	20	
				Whole fish	100	50	10	30	

TABLE 4A (Cont'd.)

Radionuclide Concentrations in Bottom-feeding Fish

Collected on the Clinch and Tennessee Rivers, September, 1960.

Species(9)	Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight)				
					Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}**
Carp	471.0 TRM	1	1871	Flesh	35	30	15	45	170 ± 10
				Bone	180	25	10	20	660 ± 35
				Viscera	440	60	75	90	
				Whole fish	150	40	30	50	

* Values below limits of detectability.

** Strontium-90 values reported only for samples analyzed.

TABLE 5A

Radionuclide Concentrations in Gizzard Shad(9)

Collected on the Clinch and Tennessee Rivers, September, 1960.

Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight) Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}**
CRM 79.8	2	227	Whole fish	190	45	70	85	80 ± 5
CRM 19.6	2	140	Whole fish	95	90	100	90	1100 ± 35
CRM 4.5	1	908	Flesh	---*	360	90	10	280 ± 20
			Bone	---	410	890	320	980 ± 70
			Viscera	8,600	19,000	---	1,800	
			Whole fish	1,500	3,600	120	340	
TRM 517.3	1	312	Structure	75	420	80	85	4200 ± 25
			Viscera	290	290	820	10	
			Whole fish	100	400	180	75	
TRM 517.3	1	284	Structure	65	110	85	25	360 ± 5
			Viscera	110	---	600	380	
			Whole fish	70	100	140	65	
TRM 517.3	1	284	Structure	110	140	120	90	1200 ± 15
			Viscera	8,200	5,100	290	890	
			Whole fish	1,700	1,100	160	240	
TRM 517.3	1	255	Structure	---	110	90	30	430 ± 5
			Viscera	650	280	790	180	
			Whole fish	85	130	180	50	

TABLE 5A (Cont'd.)

Radionuclide Concentrations in Gizzard Shad(9)

Collected on the Clinch and Tennessee Rivers, September, 1960.

Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight)				
				Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}**
TRM 517.3	1	227	Structure	---	220	100	100	3100 ± 25
			Viscera	---	190	410	100	
			Whole fish	---	220	160	100	
TRM 517.3	12	822	Structure	---	120	50	30	1300 ± 60
			Viscera	1,500	140	340	360	
			Whole fish	200	120	90	75	

* Values below limits of detectability.

** Strontium-90 values reported only for samples analyzed.

TABLE 6A

Radionuclide Concentrations in Sight-feeding Fish

Collected on the Clinch and Tennessee Rivers, September, 1960.

Species[9]	Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight) Ru^{106}	Cs^{137}	$Zr^{95}-Nb^{95}$	Co^{60}	Sr^{90}**
Sauger	CRM 79.8	2	1162	Flesh	60	190	60	90	30 ± 15
				Bone	30	25	100	25	170 ± 35
				Viscera	120	50	140	---*	
				Whole fish	65	130	85	60	
Channel catfish	CRM 79.8	1	198	Whole fish	100	15	150	70	130 ± 5
Striped bass	CRM 79.8	3	3005	Flesh	15	340	95	120	130 ± 5
				Bone	---	30	130	70	430 ± 30
				Viscera	75	65	65	60	
				Whole fish	35	160	95	85	
Longnose gar	CRM 19.6	1	228	Flesh	55	410	180	10	150 ± 20
				Bone	2,600	650	1,500	300	5800 ± 90
				Viscera	630	60	540	---	
				Whole fish	370	380	350	35	
Crappie	CRM 14.6	1	71	Whole fish	---	100	300	130	
Channel catfish	CRM 14.6	1	1049	Flesh	150	160	40	30	280 ± 10
				Bone	---	250	250	150	13000 ± 420
				Viscera	---	420	---	110	
				Whole fish	80	260	50	70	

TABLE 6A (Cont'd.)

Radionuclide Concentrations in Sight-feeding Fish

Collected on the Clinch and Tennessee Rivers, September, 1960.

Species[9]	Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight) Ru^{106}	Cs^{137}	$Zr^{95}-Nb^{95}$	Co^{60}	Sr^{90}**
Channel catfish	CRM 14.6	1	709	Flesh	75	1,100	50	150	800 ± 25
				Bone	---	650	490	5	190 ± 25
				Viscera	950	1,000	100	310	
				Whole fish	260	1,000	110	170	
Water drum	CRM 14.6	1	85	Whole fish	---	200	200	50	400 ± 15
Smallmouth bass	CRM 4.5	1	1729	Flesh	---	2,200	100	100	850 ± 50
				Bone	310	770	320	---	19000 ± 330
				Viscera	45	400	80	40	
				Whole fish	45	1,700	120	75	
Crappie	CRM 4.5	2	85	Whole fish	370	510	40	150	1500 ± 40
Water drum	CRM 4.5	2	114	Whole fish	340	530	170	90	4000 ± 130
Bullhead	CRM 4.5	3	199	Flesh	---	1,100	640	60	490 ± 60
				Bone	260	280	470	---	7400 ± 400
				Viscera	2,500	660	560	340	
				Whole fish	860	690	560	130	
Sauger	CRM 4.5	8	1760	Flesh	20	1,500	70	70	6700 ± 130
				Bone	---	440	320	---	5700 ± 160
				Viscera	440	660	90	180	
				Whole fish	55	1,300	100	70	

TABLE 6A (Cont'd.)

Radionuclide Concentrations in Sight-feeding Fish

Collected on the Clinch and Tennessee Rivers, September, 1960.

Species(9)	Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight) Ru^{106}	Cs^{137}	$Zr^{95}-Nb^{95}$	Co^{60}	Sr^{90**}
Blue catfish	TRM 517.3	5	1276	Flesh	---	55	75	75	550 ± 90
				Bone	---	5	160	50	4500 ± 110
				Viscera	---	40	100	15	
				Whole fish	---	40	95	55	
Blue catfish	TRM 517.3	3	425	Flesh	65	140	65	80	180 ± 5
				Bone	---	120	390	110	1100 ± 25
				Viscera	1,000	480	410	520	
				Whole fish	155	170	140	130	
Flathead catfish	TRM 471.0	1	3000	Flesh	170	290	50	150	30 ± 2
				Bone	110	40	100	60	1700 ± 95
				Viscera	45	260	70	90	
				Whole fish	120	230	65	110	
White bass	TRM 471.0	3	851	Flesh	30	140	15	40	520 ± 85
				Bone	50	---	530	90	1200 ± 120
				Viscera	120	---	760	190	
				Whole fish	40	120	120	55	
Channel catfish	TRM 471.0	1	1276	Flesh	---	95	45	110	310 ± 15
				Bone	---	60	160	85	3700 ± 200
				Viscera	240	140	140	70	
				Whole fish	60	100	90	95	

TABLE 6A (Cont'd.)

Radionuclide Concentrations in Sight-feeding Fish

Collected on the Clinch and Tennessee Rivers, September, 1960.

Species[9]	Collection point	No.	Live weight, grams	Fraction	Activity, μμc/kg (live weight)				
					Ru^{106}	Cs^{137}	$Zr^{95}-Nb^{95}$	Co^{60}	Sr^{90}**
Channel catfish	TRM 471.0	1	709	Flesh	---	10	70	90	170 ± 10
				Bone	160	---	410	260	2700 ± 110
				Viscera	510	---	110	75	
				Whole fish	170	6	110	100	

* Values below limits of detectability.

** Strontium-90 values reported only for samples analyzed.

[redacted]

GB#12

REPORT ON CLINCH RIVER SAMPLES

COLLECTED FEBRUARY 9-15, 1960 BY PERSONNEL OF THE

U. S. PUBLIC HEALTH SERVICE

I. <u>General</u>

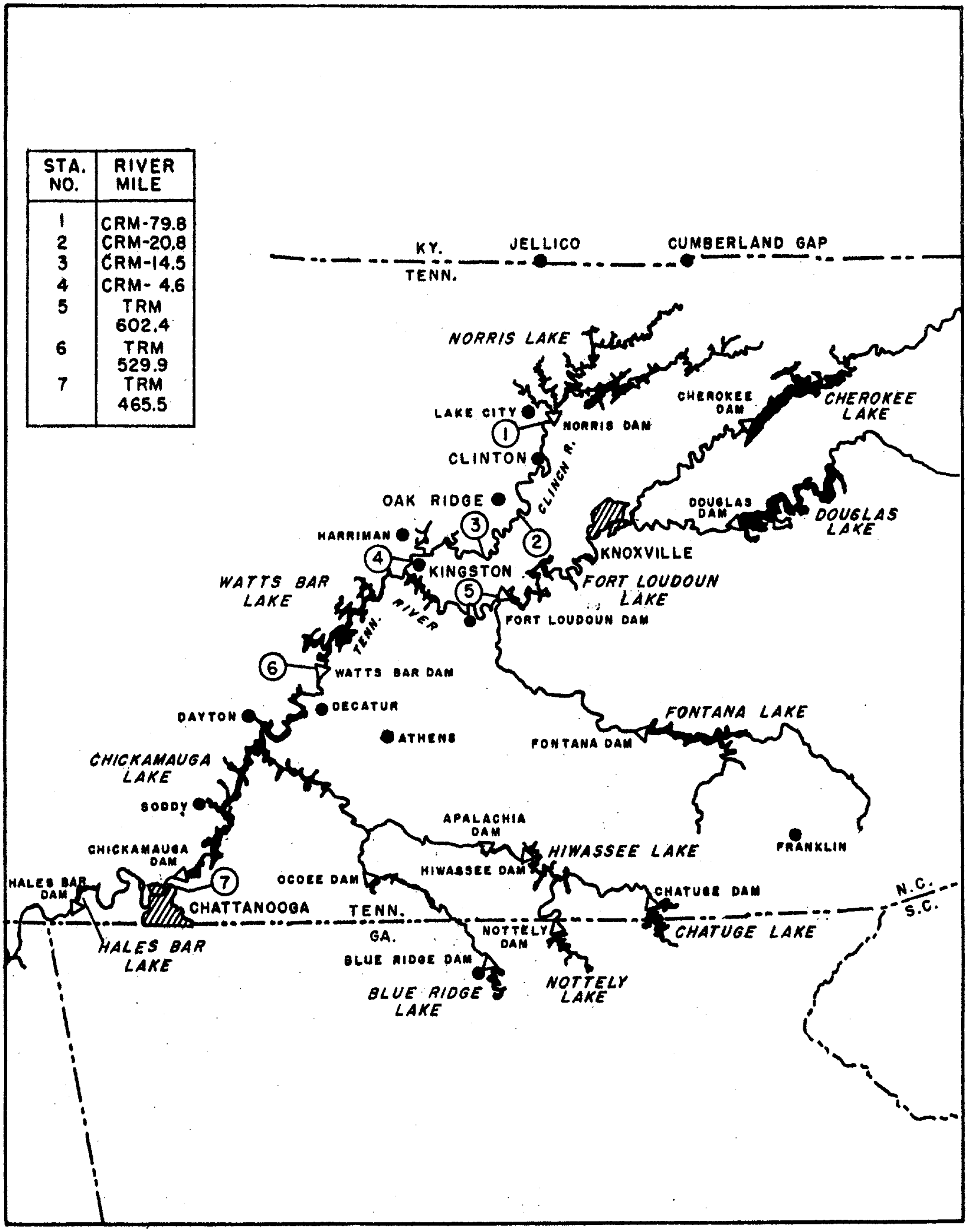
Samples of biota, mud, and water from the Clinch River were collected by personnel of the Cooperative Studies Unit, Radiological Health Research Activities, Division of Radiological Health, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio during the period February 9-15, 1960. Personnel from the Center who participated in this sampling were Dr. A. G. Friend, Mr. A. H. Story, Mr. M. Howell, and Mr. C. Henderson. The first three of these participants named are Sanitary Engineers attached to the Radiological Health Research Activities at the Center and the latter is an Aquatic Biologist with the Research Section of Water Supply & Water Pollution Control also at the Center.

Persons contacted during this trip were: Mr. Larry Miller, Chief of the Fish & Game Department, and Mr. Jack Chance, Fish Biologist, both of TVA at Norris, Tennessee; Mr. Wilbur Kochtitzky, Mr. Milo Churchill, Mr. Ward Filgo, and Mr. Buckingham of TVA in Chattanooga, Tennessee; Mr. Swearingen, Plant Superintendent of the Chattanooga Water Treatment Plant; Mr. Ralph Sinclair, and Mr. Harold Mulligan of the Tennessee Water Pollution Control Board; Mr. Price Wilkins and Mr. Ed Manges of the Tennessee Fish & Game Department; Dr. Frank Parker, Dr. Dan Nelson, Mr. Roy Morton, Mr. Ray Richardson, and Mr. Ken Cowser of the Health Physics Section, ORNL; and Mr. John Latendresse, Mr. Cecil ("Meatball") Morse, and Mr. J. P. Lyons, all the latter being commercial fishermen in this area.

II. General Biological Conditions

It is difficult to describe the general biological conditions in the area covered by this survey (Norris Reservoir to Chattanooga) because of the greatly different conditions in some sections. The area is generally impounded water with the exception of a 50 mile stretch of the Clinch River below Norris Reservoir. This stretch of the Clinch River is fast, clear water--quite cold (due to releases from the bottom of Norris Reservoir) and contains a different biota from the remainder of the area. A fair rainbow trout sport fishery has been reportedly developed in this stretch of river.

The remaining reservoir waters contain generally mixed populations of warm water game, forage, and rough species of fish. Norris Reservoir is somewhat different from Watts Bar and Chickamauga due mainly to its depth and to its sharply declining shoreline as well as to its cleaner, colder waters. Thus while fishes present in the remainder of the system may be common, Norris is generally noted for its Walleye and smallmouth bass sport fishery. The other reservoirs are generally considered as the crappie, bluegill, largemouth bass type of sport fishery. The tailwaters, however, sometimes furnish fabulous fishing for such reservoir species as sauger and white bass as well as for large catfish.



LOCATION OF SAMPLING STATIONS ON CLINCH & TENNESSEE RIVERS

FIGURE 1

The whole study area, with the possible exception of the Clinch River from White Oak Creek to Kingston is used quite extensively by sport fishermen.

Commercial fishermen also use most of the study area where an extensive fishery for rough and food species has been developed. Most of the fishing is with trammel nets (3" - 5" mesh) and the major species caught are paddlefish, carp, carpsuckers, redhorse and catfish. There is also some hook-and-line fishing for catfish. All of the area is open to unlimited commercial fishing except Norris Reservoir in which commercial fishing is permitted only during certain periods. The taking of game species in nets is not permitted.

Other species of fish which are quite common, are the gizzard shad, skipjack herring, and gar. While furnishing some forage for other fish they are generally considered a nuisance.

A fairly extensive commercial fishery for mussels has also been developed in the area.

Altogether the whole area is widely used by sport and commercial fishermen as well as for general water recreational activities and its use for such purposes is widely acclaimed.

III. <u>Location of Sampling Stations and Samples Collected</u>

Figure 1 is a map showing the general area under study along with the location of the sampling stations, a description of which follows.

A. Station 1

Station 1 was the area above Norris Dam (CRM 79.8). The water sample from Station 1 was collected from the concession stand approximately 1/4 mile north of Norris Dam. The mud sample was collected in the vicinity of Pellissippi boat dock, approximately six miles above the dam on the Clinch River arm of the reservoir. One large fish sample was collected from the mouth of the cove at the boat dock and the other two fish samples were furnished by Mr. John Latendresse. These latter fish were collected from the upper reaches of Norris Reservoir where commercial fishing was going on at the time of this trip. The minnows from Station 1 were collected from a small stream flowing into the reservoir about three miles above Norris Dam by Mr. Mulligan and Mr. Sinclair of the Water Pollution Control Board.

In the stretch of the river between Norris Dam and White Oak Creek, about twenty miles below Norris Dam, a sample of filamentous algae and one live clam were collected.

B. Station 2

The water sample from Station 2 was collected from White Oak Creek about 50 feet above its point of entry into the Clinch River (CRM 20.8). Fish samples were collected from the mouth of White Oak Creek and at a point about 150 yards downstream from the mouth. Bottom mud samples were collected in the vicinity of the dam on White Oak Creek, at the mouth of White Oak Creek and from the Clinch River about 150 yards downstream from the mouth. A sample of soil was also taken from the creek bank near the mouth of White Oak Creek.

C. Station 3

The water sample collected at Station 3 was taken from the center pier of the Gallaher Bridge (CRM 14.5) located near the mouth of Grassy Creek. Bottom mud samples were collected about one mile below the mouth of Poplar Creek (CRM 12.0) at buoy 10.9 and about 200 yards below the point of entry of Poplar Creek into the Clinch River. Fish samples were collected just above and just below Gallaher Bridge. A medium-size eastern painted turtle was collected in the gill net just below Gallaher Bridge. We are indebted to Mr. Ed Manges of the Tennessee Fish and Game Commission for his aid in collecting the fish samples at Station 3.

D. Station 4

The water sample from Station 4 was collected on the south bank of the Clinch River at Centers Ferry (CRM 4.6) almost opposite the point where the Emory River enters the Clinch. Mud samples were collected at the mouth of the Emory River and about 1/4 mile above Centers Ferry in the Clinch River. Large fish from Station 4 were collected about 1/2 mile below Highway 70 Bridge west of Kingston (CRM 2.2). The small fish sample at Station 4 was collected at the same point as the mud samples about 1/4 mile above Centers Ferry.

E. Station 5

The water sample at Station 5 was collected immediately above the face of the Fort Loudoun Dam (TRM 602.4). We are indebted to the

Security Officers at the Dam for changing sample bottles every day, thus relieving us of the necessity of visiting this sampler daily. The mud samples from Fort Loudoun Reservoir was collected about eight miles above the dam at a public picnic area. The fish samples were collected from the same area. For these fish collections we are indebted to Mr. Price Wilkins, Principal Trout Biologist of the Tennessee Fish and Game Department, who accompanied us to this area and furnished the boat and motor with which the collections were made.

F. Station 6

The water sample from Station 6 was collected from the tail race below Watts Bar Dam (TRM 529.9). The mud sample (sand) was collected about 1/2 mile below the Dam. A sample of clam shell from this same area was also collected for analysis.

G. Station 7

The water samples from Station 7 were collected by Mr. Swearingen, Plant Superintendent of the Chattanooga Water Treatment Plant. These daily samples consisted of hourly composites of both the raw intake water and the treated water. Mr. Swearingen also collected for us a sample of settled filter sludge approximately eight months old, a sample of back-wash water, and a sample of used filter sand from the Chattanooga Water Treatment Works. Mud samples were collected from the upstream face of the Chickamauga Dam (TRM 469.9) and from South Chickamauga Creek about 1/4 mile from its mouth and below the heavy metals industries, the effluents of which were discharged into this creek. Fish collected at

Station 7 consisted of four catfish from the vicinity of Hixson, Tennessee in the Chicamauga Reservoir in the vicinity of TRM 477. One medium sized gizzard shad was collected immediately below the Chickamauga Dam and a sample of buffalo was collected at Hales Bar Dam near Shellmound, Tennessee in the vicinity of TRM 425.

In addition to the above samples three bottom mud samples were collected from Bear Creek on the Oak Ridge Reservation. A complete listing of all samples analyzed is shown in Table 1. In some instances, however, the numbers do not indicate individual samples collected during the trip but samples analyzed, e.g., an individual fish may furnish from one to seven samples when separated into component parts for analytical purposes.

IV. Collection and Preservation of Samples

A. Bottom Muds

Mud samples were collected with either an Eckman or Pederson dredge depending on the composition of the bottom. In general the Pederson dredge was only used where the bottom deposits contained pebbles or hard clayey materials.

The samples were placed into standard pint-sized plastic containers for storage, transportation, and subsequent gamma counting.

No preservatives were used for bottom mud samples.

B. Water

Where possible, water samples were collected on a continuous basis during the entire collecting period by means of a commercial sampler.

TABLE 1

TYPE AND QUANTITY OF SAMPLES FROM EACH STATION

Sample Type	Station Number 1	2	3	4	5	6	7	X	Type Totals
Algae bags		5						10	15
Clam (shells)	1					1			2
Crayfish	1								1
Fil. algae	1								1
Filter sand							2		2
Fish	18	6	40	38	9		16		127
Mud	1	4	4	2	1	1	2	4	19
Plankton tow	1		1	1	1				4
Rock								1	1
Sand Wash H_2O							3		3
Sludge							1		1
Spinach bags		5						6	11
Snails	1								1
Tea bags		11						13	24
Turtle			1						1
Water	1	6	5	1	1	1	2		17
Station Totals	25	37	51	42	12	3	26	34	230

1 - Clinch River at Norris Dam (CRM 79.8)
2 - Clinch River at White Oak Creek (CRM 20.8)
3 - Clinch River at Gallaher Bridge (CRM 14.5)
4 - Clinch River at Centers Ferry (CRM 4.6)
5 - Tennessee River at Fort Loudoun Dam (TRM 602.4)
6 - Tennessee River at Watts Bar Dam (TRM 529.9)
7 - Tennessee River at Chattanooga, Tenn.
X - Three different locations on Bear Creek

No sampler was placed at Station 6. The sample from that station represents a composite of two 2-gallon grab samples. Samples from Station 7 were hourly grab samples were composited daily to make a 2-gallon per day sample. The samples from Station 7 were collected by the operators of the Chattanooga Water Treatment Plant.

All water samples were stored and shipped in 2-gallon polyethylene bottles.

C. Biota

Separate plankton samples for numerical count and weight were collected by dipping a water composite (1 gallon for count, 2 gallons for weight) from the surface while traveling across the watercourse. At the same time a No. 20 (173 meshs per inch) plankton net was being towed to collect a sample for radionuclide analysis. The sample for count was preserved with merthiolate and the other samples with 5% formalin for return to the laboratory.

Numerical plankton counts were made by Dr. Louis G. Williams of The Robert A. Taft Sanitary Engineering Center by the same procedure used in the USPHS Basic Data Program. This method consists of a direct clump count using 2 strips instead of 10 fields of a Sedgewick-Rafter counting cell at a magnification of 200.

The samples for plankton weight (usually 5 liters) were centrifuged in a Foerst Centrifuge and air-dried and ashed (600°C for 30 minutes) weights obtained.

The sample for radionuclide determination was filtered through No. 2 filter paper in a Buchner funnel and filtered and air-dried weights obtained.

D. Fish

Small fish were collected by seining with 1/4" mesh nets in slough or shallow water areas. Large fish were collected by bottom sets with 1", 2" and 3" nylon gill nets or were obtained from commercial fishermen in the area. Fish samples were preserved in 10% formalin for transport to the laboratory. They were then identified, measured, weighed and separated into parts or organs as desired for radionuclide analysis.

A few other biological samples such as filamentous algae and bottom organisms were picked up when found and preserved in 10% formalin. No attempt was made to systematically collect bottom organisms as this phase of the program was to be carried out by the group at ORNL.

During the survey period, commercial fishing was being conducted in Norris Reservoir and from Kingston downstream in the rest of the study area. Some sport fishing, mainly for sauger and white bass was being carried out, principally in the tailwaters of Watts Bar and Chickamauga Reservoirs.

The principal collections were made in the Clinch River between the mouth of White Oak Creek and Kingston where commercial fish were not available. Shad, white bass and sauger predominated in gill net catches.

The following species of fish were identified from our collections:

Skipjack herring	Alosa chrysochloris
Gizzard Shad	Dorosoma cepedianum
Carp	Cyprinis carpio
Spotfin shiner	Notropis spilopterus
Bluntnose minnow	Pimephales notatus
Bullhead minnow	Pimephales vigilax
Blacknose dace	Rhinichthys atratulus
River carpsucker	Carpiodes carpio
Quillback	Carpiodes cyprinus
Smallmouth buffalo	Ictiobus bubalus
Bigmouth buffalo	Ictiobus cyprinellus
Channel catfish	Ictalurus punctatus
White bass	Roccus chrysops
Bluegill	Lepomis macrochirus
Smallmouth bass	Micropterus dolomeiui
Largemouth bass	Micropterus salmoides
Logperch	Percina caprodes
Sauger	Stizostedion canadense
Sculpin	Cottus sp. carolinae ?
Brook silverside	Labidesthes sicculus

V. Preparation of Samples

A. Bottom muds

No special preparation was given to bottom mud samples. They were weighed in their container and placed directly onto the crystal for gamma scanning. The activity of the samples from Stations 2 and 3 was too high to be counted by the usual method so that approximately 5 grams, more or less--depending upon the activity of the sample--were air dried, weighed, and counted on a stainless steel planchet.

For all mud samples corrections were made for self-absorption.

B. Water

Water samples were composited by combining a gallon of water per day giving a ten gallon sample for each station. These samples were then evaporated down to 3.5 liters and counted on the gamma spectrometers in the standard 3.5-liter milk beakers. The water sample was analyzed for strontium-90 after gamma scanning.

C. Fish

After being separated into species, the fish were divided into various parts. These component parts were placed in the standard plastic counting and storage containers, preserved with formalin and counted on the gamma spectrometer. For strontium-90 analyses the samples were ashed at 600°C in a muffle furnace.

D. Other aquatic fuana

Clams were divided into two parts, shell and flesh. These were gamma scanned and the shells were ashed and analyzed for strontium-90.

The crayfish and snails were ashed, placed in plastic containers and scanned. After scanning these samples were submitted for strontium-90 analysis.

The turtle was placed alive in a small cardboard box and set directly onto the crystal. No strontium-90 analysis was made.

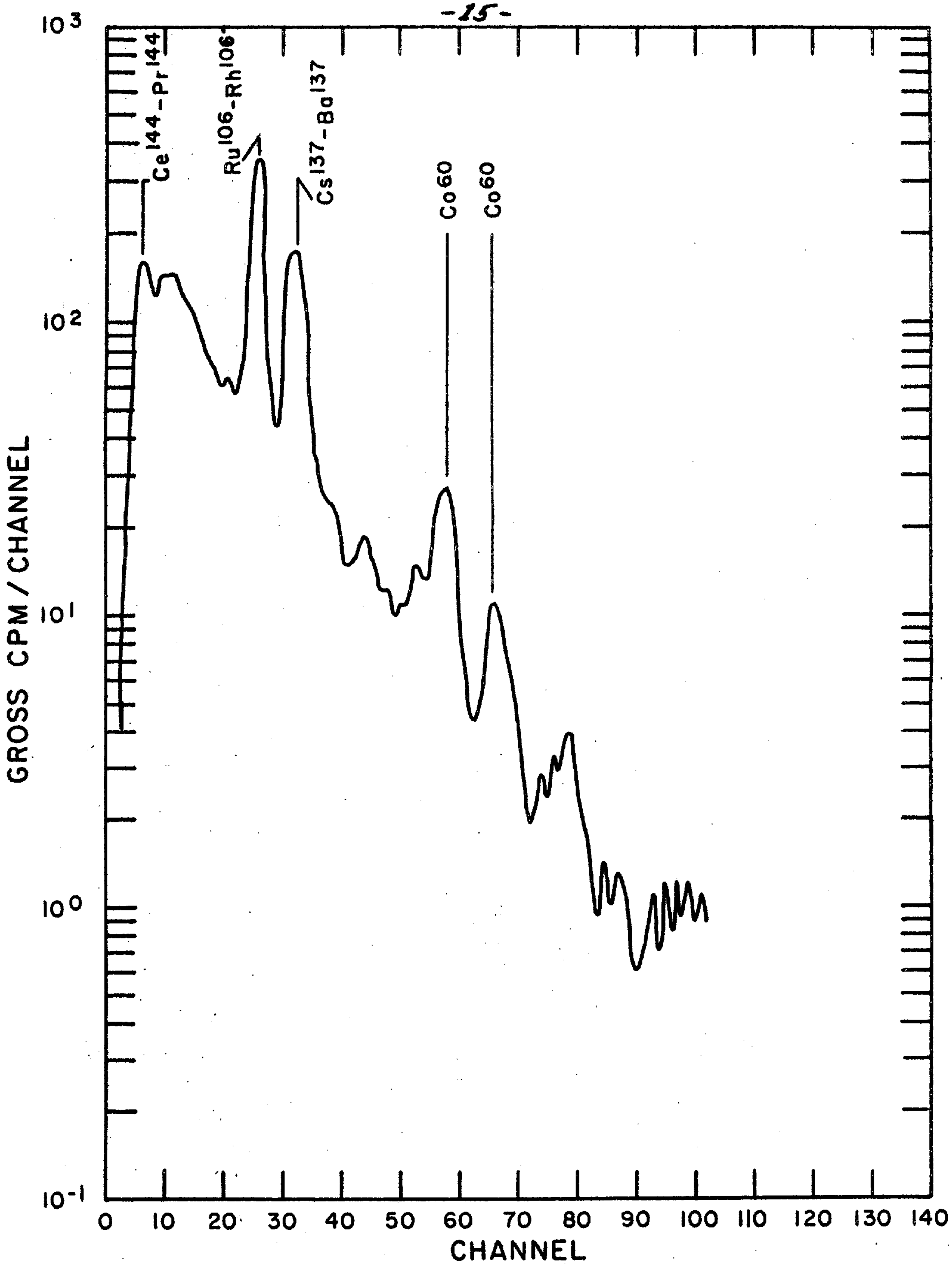
E. Plankton

No special preparation was given to plankton. After filtering, the filters were placed in stainless steel planchets and counted on the gamma spectrometers. No strontium-90 analyses were made on plankton.

VI. Results

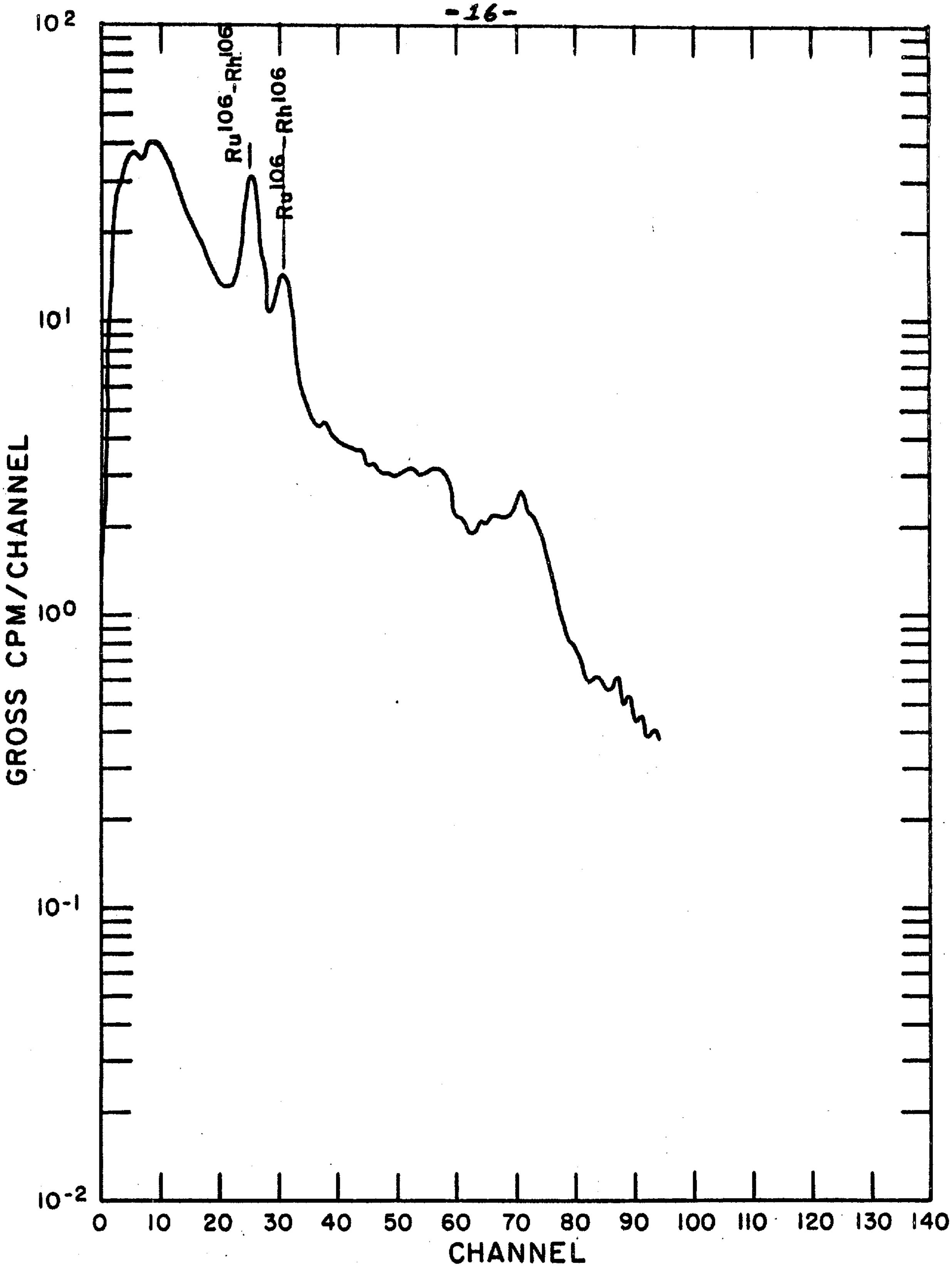
A. Water

Sample gamma spectra of water collected from White Oak Creek and from the Clinch River at Kingston, Tennessee are shown on Figures 2 and 3 respectively. Radionuclide concentrations for these various samples are shown in Table 2. The predominant radioisotopes found were cerium-144-praseodymium-144, ruthenium-106-rhodium-106, cesium-137-barium-137m, cobalt-60, and strontium-90. Traces of zirconium-95-niobium-95 and possibly zinc-65 were indicated by these spectra. Plots of the activities of the various isotopes at the various stations are shown in 4. From this plot it will be noted that the cerium-144-praseodymium-144 and cobalt-60 disappear from the water phase quite rapidly--little activity from either of these nuclides being noted beyond Station 3. Cesium-137 also seems to disappear from the water phase quite rapidly--noactivity from this isotope being indicated below Station 4. The ruthenium and strontium, however, appear to remain in the



GAMMA SPECTRUM OF WATER
COMPOSITE, WHITE OAK CREEK- 0-3.9 MEV. 10 MIN.

FIGURE 2



GAMMA SPECTRUM OF WATER
CLINCH RIVER, KINGSTON, TENN. -0-1.9 MEV. 600 MIN.

FIGURE 3

TABLE 2

RADIONUCLIDE CONCENTRATION IN WATER AT VARIOUS STATIONS AT CLINCH AND TENNESSEE RIVERS

Feb. 9 - 15, 1960

Station	Ce^{144}-Pr^{144} pc/l	Ru^{106}-Rh^{106} pc/l	Cs^{137}-Ba^{137m} pc/l	Zr^{95}-Nb^{95} pc/l	Zn^{65}	Co^{60}	Sr^{90}*
1 (CRM 79.8)	---	---	---	---	---	---	0.5
2 (CRM 20.8)	985	14,300	2150	T	---	321	2825
3 (CRM 14.5)	625	940	270	---	---	17	19.7
4 (CRM 4.6)	---	860	27	T	---	T	5.8
5 (TRM 602.4)	---	---	---	---	---	---	0.4
6 (TRM 529.9)	---	86	---	T	---	T	1.5
7 (Raw) (TRM 465.5)	---	250	---	---	T	T	4.4
7 (Treated) (TRM 465.5)	---	170	---	---	---	T	3.6

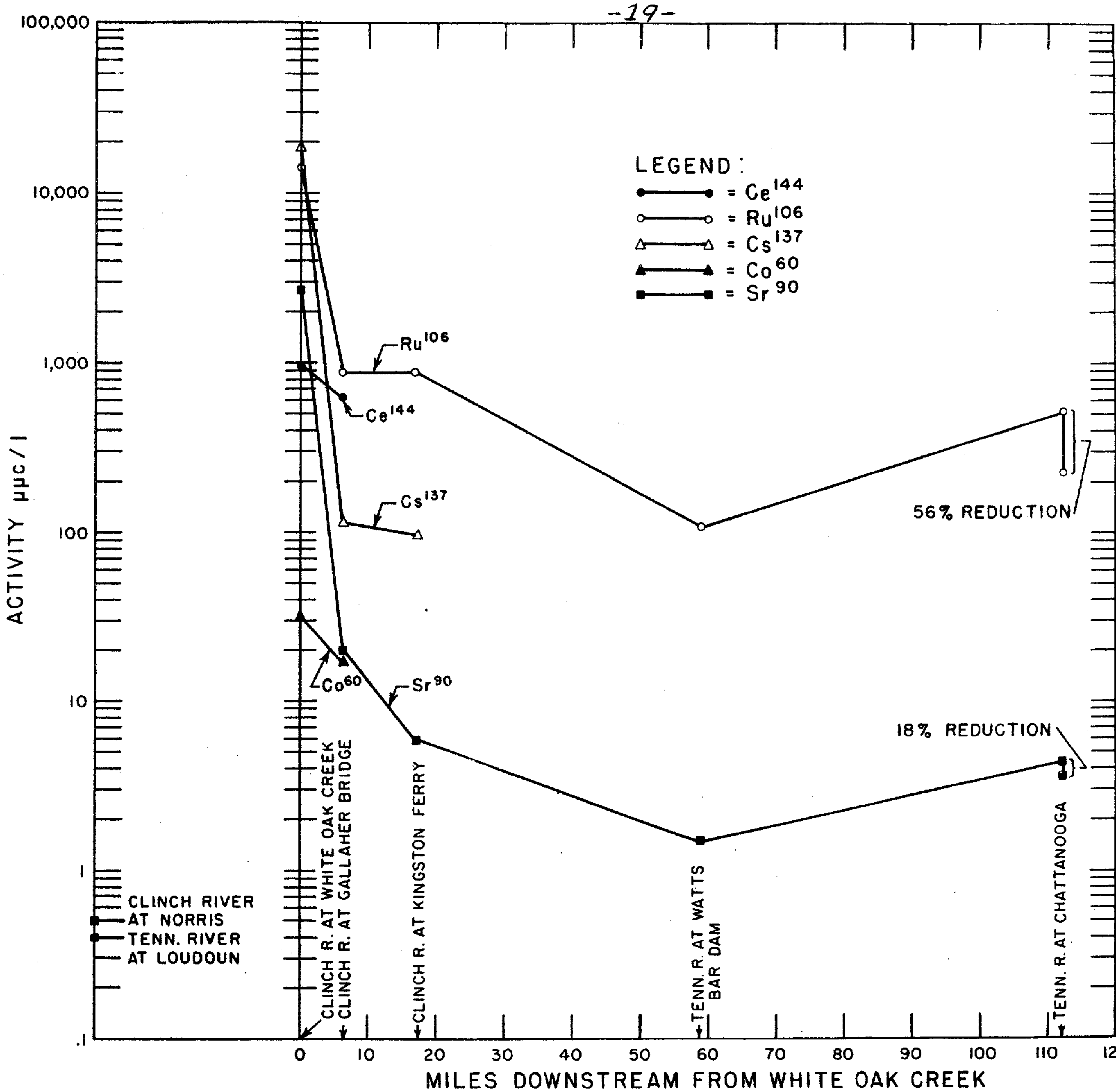
* Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

water phase for appreciable lengths of time as indicated by the plots on Figure 4 for these elements. It is probable that this rapid reduction in concentration in the water phase is due to the uptake of cerium-144-praseodymium-144, cobalt-60, and cesium-137-barium-137m by the bottom muds either due to ion exchange, to adsorption, or to precipitation.

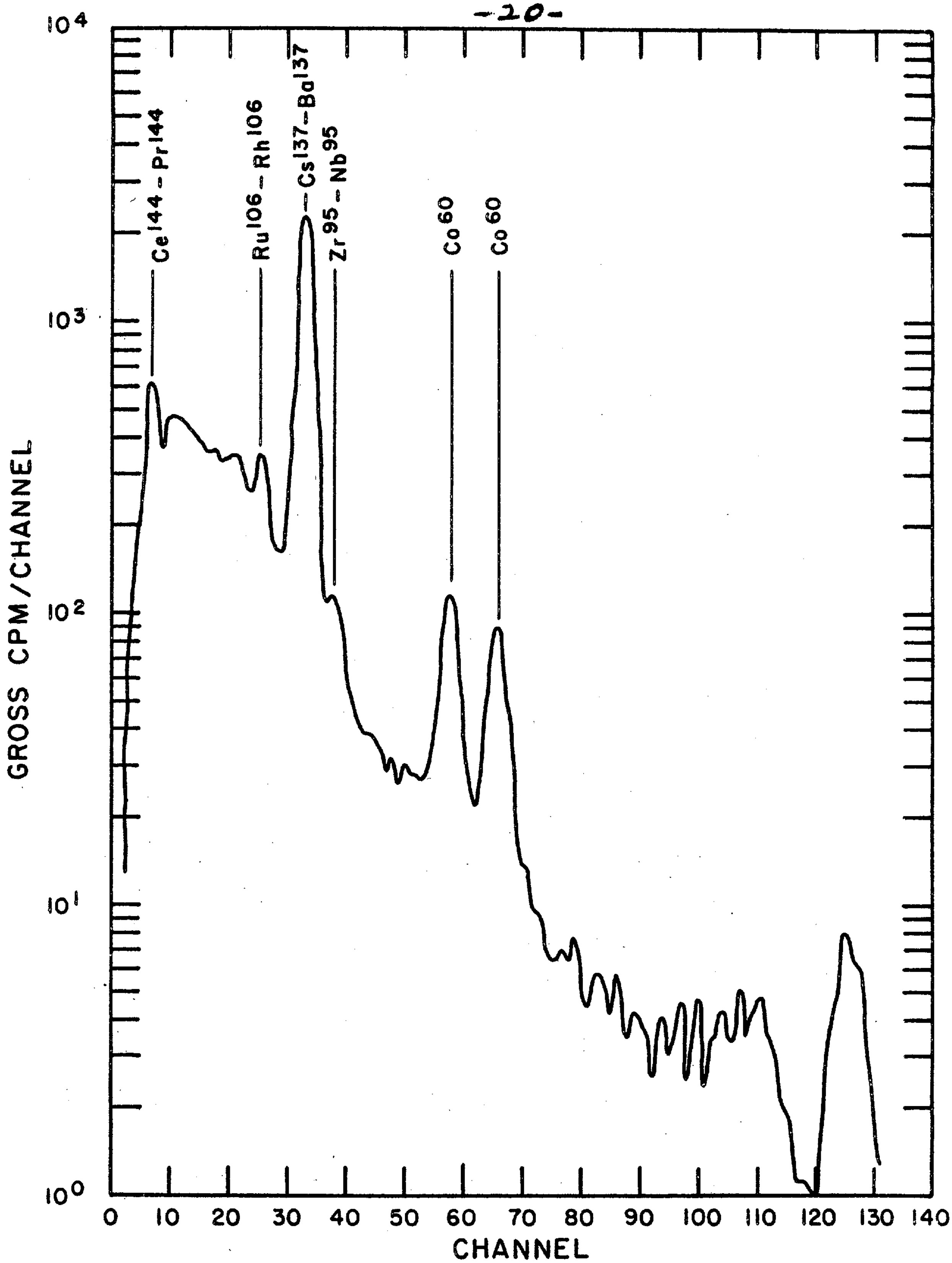
B. Bottom Muds

Sample gamma spectra of bottom mud samples collected from White Oak Creek and the Clinch River at Kingston are shown in Figures 5 and 6 respectively. It will be seen that the same isotopes found in the water also appear in the spectra of the bottom muds with much higher concentrations. Radionuclide concentrations for these various samples are shown in Table 3. A plot showing the concentrations of the various radionuclides in the bottom muds is shown in Figure 7. The low values shown at Station 6 which were collected at Watts Bar Dam are probably due to scour in this area and also to the fact that the mud sample from this station showed very little clay content from visual inspection, the main component being sand which has very low ion exchange capacity. The high concentrations further down the river at the face of Chickamauga Dam were consequently due to the deposition of materials transported by the river or may be due to ion exchange _in situ_. Also it is likely that the sample was not representative of the river since it consisted of 3 grab samples. Corresponding nuclide concentration in the bottom muds as determined from tributary samples are shown in Table 4. As might



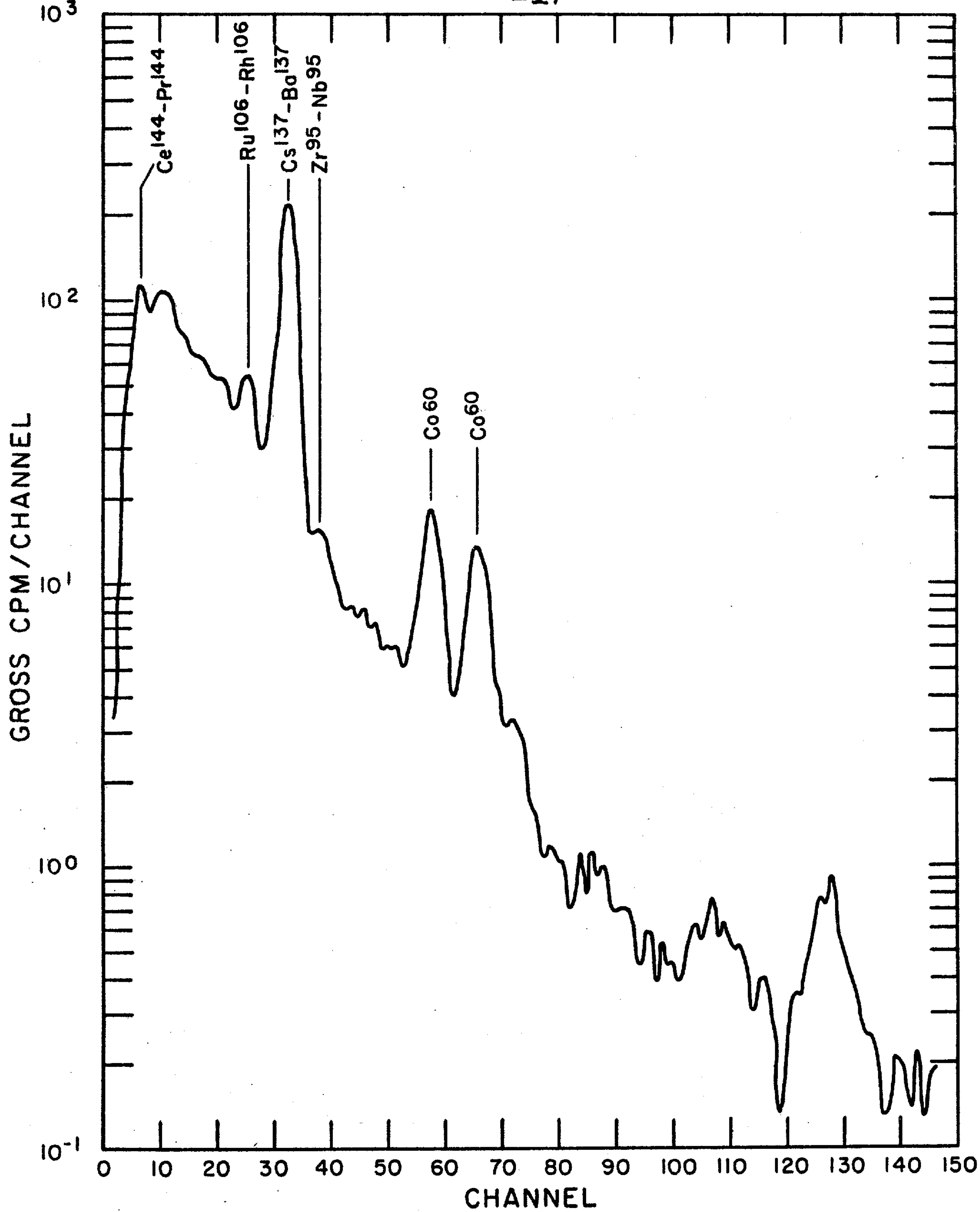
RADIONUCLIDE CONCENTRATION IN WATER
CLINCH AND TENNESSEE RIVERS

FIGURE 4



GAMMA SPECTRUM OF BOTTOM MUDS
MOUTH OF WHITE OAK CREEK - 0-3.9 MEV. 10 MIN.

FIGURE 5



GAMMA SPECTRUM OF BOTTOM MUDS
CLINCH RIVER, KINGSTON, TENN. - 0-3.9 MEV. 100 MIN.
FIGURE 6

TABLE 3

RADIONUCLIDE CONCENTRATIONS IN BOTTOM MUD SAMPLES FROM THE CLINCH AND TENNESSEE RIVERS

Feb. 9 - 15, 1960

Samples Location	Ce^{144}-Pr^{144} pc/kg*	Ru^{106}-Rh^{106} pc/kg*	Cs^{137}-Ba^{137m} pc/kg*	Zr^{95}-Nb^{95} pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Ft. Loudoun Reservoir	$1.58x10^3$	---	T	105	---	---	283
Norris Dam Reservoir	$1.17x10^3$	626	T	104	---	---	74
Clinch River at mouth of White Oak Creek	$2.32x10^6$	$2.44x10^6$	$8.75x10^6$	$7.6x10^4$	---	$5.1x10^5$	$9.7x10^4$
Clinch River 150' below mouth of White Oak Creek	$5.7x10^4$	$1.0x10^5$	$3.64x10^5$	$4.12x10^3$	---	$2.1x10^4$	$8.6x10^3$
Clinch River 300' above Gallaher Bridge	$2.75x10^6$	$3.98x10^6$	$3.16x10^5$	$2.36x10^5$	---	$2.5x10^5$	$5.0x10^3$
Clinch River at mouth of Emory River	$2.37x10^3$	$7.97x10^3$	$1.21x10^4$	T	---	771	900
Clinch River 1200' above Anderson Ferry	$2.22x10^4$	$7.5x10^4$	$10.15x10^4$	$1.75x10^3$	---	898	260

TABLE 3 (Continued

RADIONUCLIDE CONCENTRATIONS IN BOTTOM MUD SAMPLES FROM THE CLINCH AND TENNESSEE RIVERS

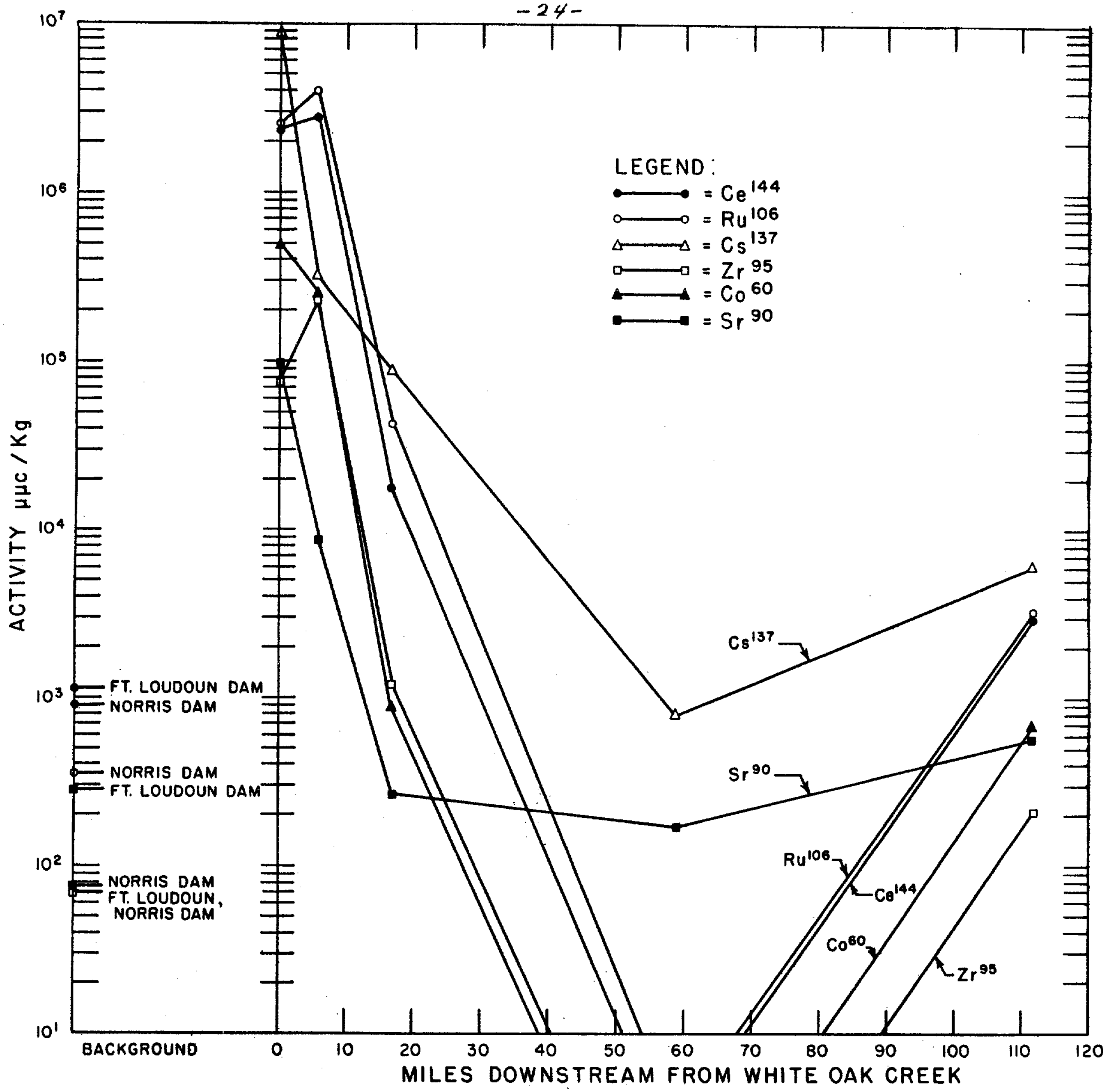
Feb. 9 - 15, 1960

Samples Location	Ce^{144}-Pr^{144} pc/kg*	Ru^{106}-Rh^{106} pc/kg*	Cs^{137}-Ba^{137m} pc/kg*	Zr^{95}-Nb^{95} pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Tennessee River below Watts Bar Dam	---	T	803	T	---	---	170
Tennessee River at face of Chickamauga Dam	3442	5969	6884	298	---	887	535

* Dry weight

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.



RADIONUCLIDE CONCENTRATIONS IN BOTTOM MUDS
CLINCH AND TENNESSEE RIVERS

FIGURE 7

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN BOTTOM MUDS OF CLINCH AND TENNESSEE RIVER TRIBUTARIES

Feb. 9 - 15, 1960

Sampling Location	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
White Oak Creek Dam	5.02×10^6	6.64×10^7	3.79×10^7	7.32×10^6	---	2.85×10^6	1.03×10^6
Mouth of White Oak Creek ℄	1.12×10^6	2.45×10^6	9.25×10^6	1.53×10^6	---	7.65×10^5	3.59×10^5
Bear Creek at White Wing Rd.	---	---	---	---	---	---	21
Ft. Loudoun	---	---	T	---	---	---	295
Bear Creek (Rock) at White Wing Rd.	---	---	T	---	---	---	63
Bear Creek, White Wing Rd. and Turnpike	---	---	T	---	---	---	
Bear Creek (gravel)	---	---	T	T	---	---	32
Poplar Creek ℄	5.86×10^5	1.2×10^6	5.0×10^6	2.96×10^4	---	3.36×10^5	802
Poplar Creek 200 yds. up from mouth	1.23×10^5	3.82×10^5	4.29×10^5	2.05×10^4	---	3.97×10^4	770
Poplar Creek 200' below K-25 fence	---	---	1.2×10^5	---	---	2.5×10^5	532
S. Chickamauga Creek	4.75×10^3	---	---	677	---	---	331

* Dry weight

** Sr^{90} values shown only for samples analysed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies

be expected, the nuclide concentration values reported for the sample collected from White Oak Creek are quite high with the presence of cerium-144-praseodymium-144, ruthenium-106-rhodium-106, cesium-137-barium-137m, zirconium-95-niobium-95, and cobalt-60 indicated. The spectra of mud samples collected from Poplar Creek also show the presence of the same nuclides as those found in the White Oak Creek samples, although the concentrations are lower by a factor of one or two orders of magnitude. Whether these isotopes found in the mud at Poplar Creek originated from White Oak Creek or whether it reflects discharge practices in the K-25 area was not determined at this time. From the data, however, it appears that the former premise is more dependable since activity levels are lower upstream in Poplar Creek than at the mouth. From the sample collected at Bear Creek little activity due to man-made nuclides appeared although peaks are present which indicate some activity due to decay products of both thorium-232 and uranium-238. The same may be said of the sample collected at Fort Loudoun Reservoir.

It has been reported that two heavy-metals industries located on South Chickamauga Creek just above Chattanooga might be responsible for the high activity levels of strontium-90 reported by the Basic Water Quality Network for Tennessee River Water at Chattanooga. While in Chattanooga we inquired as to the activity of these industries and were told that one had discontinued operation about eight months prior to this visit. In order to determine if there was a reservoir of activity in the bottom muds of the South Chickamauga Creek which might be slowly released into the water, a bottom mud sample was collected about 1/4 mile from its point of confluence with the Tennessee River. The gamma spectrum of this mud sample shows little activity due to man-made nuclides. However, peaks do indicate the presence of decay products of uranium-238 and thorium-232.

C. Fish

In general when the samples were large enough they were divided into component parts consisting of flesh; bone; scales; liver; gill, heart, and thyroid; stomach, intestines, and contents; and the remaining viscera. Each of these samples was analyzed separately in order to determine the location of specific radionuclides in the body.

1. Stations 1 and 5

Gamma scans of fish samples collected from Station 1 (Norris Reservoir) and Station 5 (Fort Loudoun Reservoir) were obtained. Nuclide concentrations are shown in Tables 5, 6, and 7. For relative values these samples were taken as background, i.e. do not reflect any influences from the discharge of White Oak Creek to the Clinch River. It will be noted that in general slight concentrations in nuclides are reported, this activity probably being due to fallout on the water shed from weapons tests.

2. Station 2

The fish collected from White Oak Creek were small and consequently it did not seem advisable to divide them into seven samples as we did for larger fish. These small fish were divided into two samples. They were gutted and the insides counted as one sample, the

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN CARP FROM NORRIS RESERVOIR, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	Ce^{144}-Pr^{144} pc/kg*	Ru^{106}-Rh^{106} pc/kg*	Cs^{137}-Ba^{137m} pc/kg*	Zr^{95}-Nb^{95} pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Scales	---	213	T	256	385	---	21
Flesh	---	---	36	14	---	---	13
Bone	---	545	372	---	---	---	22
Liver	---	T	---	---	---	---	
Intestines and Contents	---	---	---	---	---	---	
Viscera	---	390	T	---	---	---	
Ovaries	---	167	T	---	---	---	

* Live weight, 1 fish, total weight 793 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 6

RADIONUCLIDE CONCENTRATION IN QUILLBACK FROM NORRIS RESERVOIR, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Scales	---	480	110	T	---	---	
Flesh	---	---	---	---	---	---	4.0
Bone	---	440	---	70	300	---	28.5
Intestine and Contents	---	T	T	---	---	---	
Liver	---	T	T	---	---	---	
Viscera	---	---	---	---	---	---	
Gills	---	---	---	80	---	---	

* Live weight, 1 fish, total weight 803 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN CARP FROM FORT LOUDOUN RESERVOIR, TENNESSEE RIVER

Feb. 9 - 15, 1960

Sample	Ce^{144}-Pr^{144} pc/kg*	Ru^{106}-Rh^{106} pc/kg*	Cs^{137}-Ba^{137m} pc/kg*	Zr^{95}-Nb^{95} pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Scales	---	---	---	T	200	T	47
Flesh	---	---	---	---	145	---	2.9
Bone	---	---	T	770	3320	T	37.2
Gills, Heart, Thyroid	---	---	---	70	280	T	
Liver	---	---	---	100	---	---	
Intestine and Content	---	---	---	---	---	T	
Viscera	---	---	---	70	---	T	

* Live weight, 2 fish, total weight 489 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN FISHES FROM WHITE OAK CREEK

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Gizzard Shad Structure	---	43,000	12,000	T	---	3000	
Gizzard Shad Viscera	---	232,000	19,000	4,500	T	10,400	
White Bass Structure	---	8,900	1,850	60	710	---	56
White Bass Viscera	---	20,600	945	140	T	640	
Sauger Structure	---	3,600	1,400	---	T	---	16
Sauger Viscera	---	4,150	1,700	140	---	---	

* Live weight, 51 shad, total weight 615 gms, 3 white bass, total weight 135 gms, 2 sauger, total weight 161 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 9

RADIONUCLIDE CONCENTRATION IN WHITE BASS, STATION 3, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Flesh	---	---	700	30	T	T	298
Bone	710	1000	T	T	---	---	665
Viscera	---	T	---	---	---	---	
Liver	---	---	---	T	---	---	
Intestine and Content	---	---	700				
Scales	---	T	T	150	---	---	635

* Live weight, 2 fish, total weight 353 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 10

RADIONUCLIDE CONCENTRATION IN SAUGER FROM STATION 3, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Bone	---	---	T	---	---	---	485
Flesh	---	---	750	---	---	---	115
Scales	---	3300	320	---	---	---	263
Gills, Heart, Thyroid	---	3300	325	---	---	---	
Liver	---	---	T	---	T	---	
Viscera	---	---	520	---	---	---	

* Live weight, 5 fish, total weight 780 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 11

RADIONUCLIDE CONCENTRATION IN GIZZARD SHAD FROM STATION 3, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Intestine and Contents	8400	28,500	14,000	200	---	180	
Liver	---	4,200	1,320	140	450	---	
Flesh	---	---	1,100	---	900	---	1,365
Gills, Heart, Thyroid	---	2,200	2,600	T	250	---	
Viscera	4400	13,700	46,000	230	660	970	
Bone	720	1,760	1,550	60	710	---	850
Scales	---	740	470	50	110	170	1,080

* Live weight, 14 fish, total weight 1084 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 12

RADIONUCLIDE CONCENTRATIONS IN SKIPJACK HERRING FROM STATION 3, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	Ce^{144}-Pr^{144} pc/kg*	Ru^{106}-Rh^{106} pc/kg*	Cs^{137}-Ba^{137m} pc/kg*	Zr^{95}-Nb^{95} pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Scales	---	210	---	---	---	---	162
Gills, Heart, Thyroid	---	2280	77	---	180	---	
Ovaries and Testes	---	T	1200	T	---	---	
Intestine and Contents	---	800	660	---	---	---	
Liver	---	---	800	---	---	---	
Viscera	---	820	720	---	---	---	

* Live weight, 6 fish, total weight 993 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 13

RADIONUCLIDE CONCENTRATIONS IN CARP FROM STATION 3, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Intestine and Contents	---	9400	12,800	T	---	---	
Gills, Heart, Thyroid	---	---	T	---	---	---	
Liver	---	---	---	T	---	---	
Viscera	---	---	T	---	580	---	
Scales	---	---	T	---	530	---	1080
Bone	---	T	T	---	280	---	1715
Flesh	---	---	432	---	270	---	340

* Live weight, 1 fish, total weight 397 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

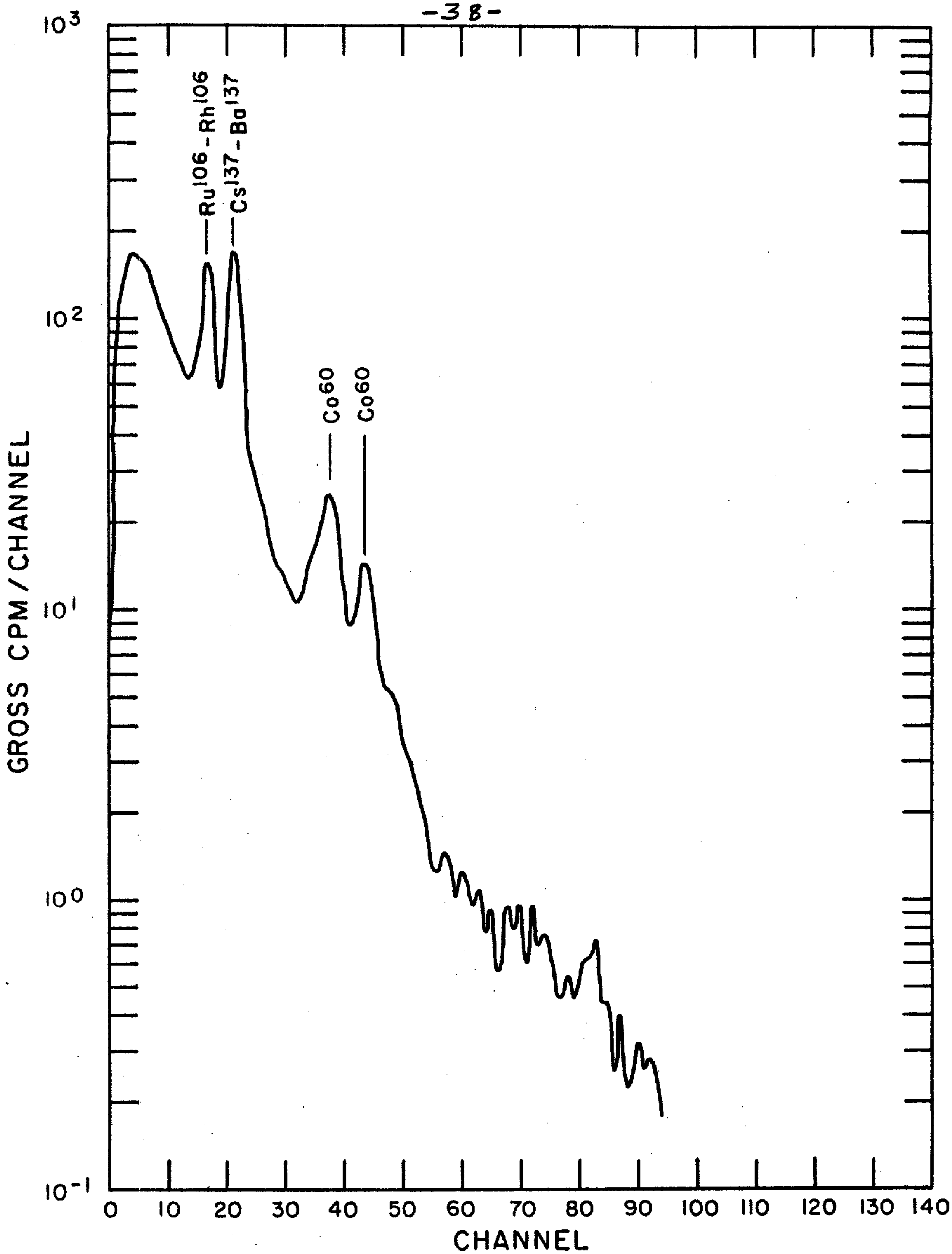
remainder of the fish counted as another.

The samples collected from White Oak Creek represent three species, gizzard shad, white bass, and sauger. A gamma spectrum obtained from the analysis of gizaard shad is shown in Figure 8. Radionuclide concentrations found in the above three species are shown in Table 8. It is interesting to note that the activities of the gizzard shad were significantly higher than those of the white bass and sauger on a per kilogram basis. This is probably due to the fact that the gizzard shad are lower in the food chain than the game species represented by the bass and sauger; and consequently, due to their feeding habits, accumulated greater quantities of all the nuclides than did the latter.

3. Station 3

Gamma scans of the component parts of two game species of fish, white bass and sauger, were obtained. Corresponding nuclide concentrations are shown in Tables 9 and 10. Since these are game species of fish the nuclide concentrations are smaller than would be the case with filter and bottom feeding fish. The concentration of nuclides from the component parts of the latter type fish are shown in Tables 11, 12, and 13.

The nuclides present in the fish collected at Station 3 are identical with those found in White Oak Creek and with the water collected from White Oak Creek; however, the corresponding levels of activity are appreciably lower. The nuclides found were cerium-144-



GAMMA SPECTRUM OF GIZZARD SHAD
WHITE OAK CREEK - 0-2.85 MEV. 50 MIN.

FIGURE 8

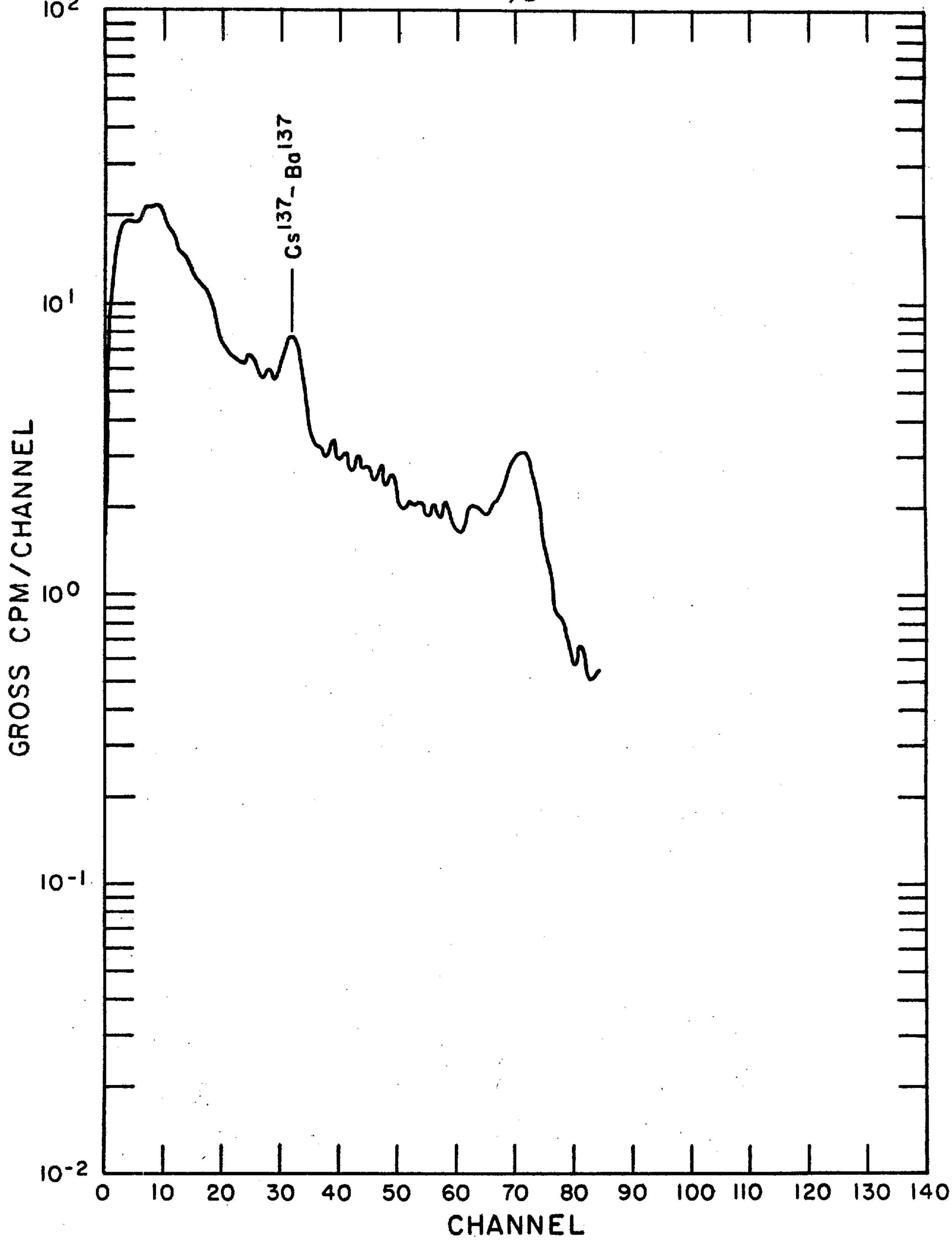
praseodymium-144, ruthenium-106-rhodium-106, cesium-137-barium-137m, zirconium-95-niobium-95, zinc-65, cobalt-60, and strontium-90.

The nuclide concentrations in the carp from Station 3 presents an interesting picture. A perusal of the values shown in Table 13 indicates that practically all the activity is tied up with the stomach, intestines, and content. One might speculate that this fish had probably spent most of its time in the Clinch River upstream of White Oak Creek or in one of the tributaries flowing into this area and that it had only recently moved into the area where it was caught. If this were true, then the high nuclide concentrations of ruthenium and cesium in the intestinal samples would indicate that this was taken up with the food and that the fish had not been able to assimilate and fix this in his body organs to any extent. Conversely one might say that the gizzard shad from this station had spent an appreciable length of his time in waters with relatively high nuclide concentrations.

4. Station 4

Three samples of game fish representing two species, sauger and smallmouth bass, were collected at Station 4. Nuclide concentrations are shown in Tables 14, 15, and 16.

Gamma scans of carp and carpsucker from this same station were obtained. Figure 9 shows a gamma spectrum of the carp flesh. Nuclide concentrations found from analyses of their component parts are shown in Tables 17 and 18. The same error in drawing conclusions concerning uptake by fish which has been stated for the smallmouth bass are more



GAMMA SPECTRUM OF CARP FLESH
CLINCH RIVER, KINGSTON, TENN. - 0-1.9 MEV. 100 MIN.

FIGURE 9

TABLE 14

RADIONUCLIDE CONCENTRATION IN SAUGER FROM STATION 4, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	Ce^{144}-Pr^{144} pc/kg*	Ru^{106}-Rh^{106} pc/kg*	Cs^{137}-Ba^{137m} pc/kg*	Zr^{95}-Nb^{95} pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Flesh	---	840	490	T	---	---	69
Bone	---	---	---	T	---	---	155
Intestine and Contents	---	2600	---	T	---	---	
Viscera	300	---	T	---	185	---	

* Live weight, 1 fish, total weight 419 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 15

RADIONUCLIDE CONCENTRATIONS IN SMALLMOUTH BASS FROM STATION 4, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Scales	2750	950	143	17	95	180	291
Flesh	---	---	600	30	63	60	500
Bone	---	690	190	30	63	---	336
Liver	---	490	370	54	390	---	
Viscera	---	---	270	---	T	---	
Intestine and Contents	---	1050	378	25	85	T	
Gills, Heart, Thyroid	---	1730	---	30	T	120	
Ovaries	---	---	---	32	---	---	

* Live weight, 1 fish, total weight 939 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 16

RADIONUCLIDE CONCENTRATION IN SMALLMOUTH BUFFALO, STATION 4, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Intestine and Content	---	T	T	---	---	T	
Gills, Heart, Thyroid	---	T	T	T	T	T	
Scales	---	490	---	---	T	---	109
Flesh	T	---	570	---	---	---	134
Bone	T	---	650	T	---	T	
Liver	---	---	---	---	---	---	
Testes	---	T	T	---	---	---	
Viscera	---	---	---	---	---	---	

* Live weight, 1 fish, total weight 770 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 17

RADIONUCLIDE CONCENTRATION IN CARP FROM STATION 4, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Scales	---	---	---	---	---	---	691
Flesh	---	---	460	T	---	---	285
Bone	---	310	T	---	---	---	808
Liver	---	---	---	41	---	---	
Gills, Heart, Thyroid	---	---	---	20	140	---	
Intestine and Contents	---	---	1000	77	145	---	
Viscera	---	---	---	73	---	---	
Ovaries	---	---	660	16	92	100	

* Live weight, 1 fish, total weight 998 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 18

RADIONUCLIDE CONCENTRATIONS IN CARPSUCKER FROM STATION 4, CLINCH RIVER

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Scales	---	---	---	40	---	---	557
Flesh	---	---	325	15	---	---	1030
Bone	---	192	23	15	---	---	1640
Liver	---	---	---	---	---	---	
Ovaries	---	---	---	---	---	---	
Gills, Heart, Thyroid	---	---	---	36	---	---	
Intestines and Content	5100	30,000	17,000	146	390	770	
Viscera	430	1600	435	---	90	140	

* Live weight, 1 fish, total weight 738 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

vividly pointed up by comparing these two samples of fish which have similar feeding habits. Here the nuclide concentrations are significantly different.

5. Station 7

A fish sample consisting of four catfish, collected from the Chickamauga Reservoir at Hixson, Tennessee, was obtained from a commercial fisherman. Nuclide concentrations are shown in Table 19. The results of the analyses of these fish for radioactivity are surprising since none of the man-made isotopes appear in concentrations large enough for determination by gamma spectroscopy, although the gamma spectra do indicate the presence of the decay products of thorium-232 and uranium-238 in measureable quantities. Strontium-90 concentrations were determined by radiochemical means. Here again one might speculate that these fish had spent all of their lives in one of the tributaries which is not effected by discharge practices of ORNL and had only recently migrated into the Tennessee River proper. Such an explanation would appear feasible provided the information obtained from the commercial fisherman was true and these fish had been caught from the Chickamauga Reservoir on the preceding day.

A gamma spectrum of a buffalo taken from Hales Bar Reservoir below Chattanooga was obtained and nuclide concentrations determined for this sample are shown in Table 20. With the exception of cerium-144-praseodymium-144 and cobalt-60, all the other expected isotopes are present, some at surprisingly high levels.

D. Miscellaneous Aquatic Fauna

TABLE 19

RADIONUCLIDE CONCENTRATION* IN CATFISH, STATION 7, TENNESSEE RIVER AT HIXSON, TENNESSEE

Feb. 9 - 15, 1960

Sample	$Ce^{144}-Pr^{144}$ pc/kg**	$Ru^{106}-Rh^{106}$ pc/kg**	$Cs^{137}-Ba^{137m}$ pc/kg**	$Zr^{95}-Nb^{95}$ pc/kg**	Zn^{65} pc/kg**	Co^{60} pc/kg**	Sr^{90}*** pc/kg**
Flesh	---	---	---	---	---	---	49.7
Ovaries	---	---	---	---	---	---	
Bone	---	---	---	---	---	---	665
Intestine and Content	---	---	---	---	---	---	
Viscera	---	---	---	---	---	---	
Gills, Heart, Thyroid	---	---	---	---	---	---	
Liver	---	---	---	---	---	---	

* All gamma activity appears to be associated with natural activity.

** Live weight, 4 fish, total weight 697 gms.

*** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

TABLE 20

RADIONUCLIDE CONCENTRATIONS IN SMALLMOUTH BUFFALO FROM TENNESSEE RIVER

AT SHELLMOUND, TENNESSEE

Sample	$Ce^{144}-Pr^{144}$ pc/kg*	$Ru^{106}-Rh^{106}$ pc/kg*	$Cs^{137}-Ba^{137m}$ pc/kg*	$Zr^{95}-Nb^{95}$ pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*	Sr^{90}** pc/kg*
Scales	---	---	T	---	---	---	95.1
Flesh	---	2600	185	---	---	---	6.3
Bone	---	1380	157	---	69	---	307.
Intestines and Contents	---	4400	207	---	---	---	
Liver	---	---	230	99	150	---	
Viscera	---	---	T	55	110	---	
Gills, Heart, Thyroid	---	---	T	---	---	---	

* Live weight, 1 fish, total weight 440 gms.

** Sr^{90} values shown only for samples analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

Gamma spectra of various aquatic animals consisting of snails, crayfish, clams, and a turtle were obtained. Nuclide concentrations where they could be calculated are shown in Table 21. In some instances the counting geometry was not determined and consequently nuclide concentrations based on these gamma scans are not possible. However, all the samples, except the turtle, were submitted for radiochemical analyses and the results obtained for strontium-90 are shown. It is significant to note the level of zinc-65 found in the snail sample which was collected from a small stream flowing into Norris Reservoir, while only traces were found in those samples collected at other places.

E. Plankton

Plankton counts indicated a very sparse population consisting mostly of diatoms. Enumeration of plankton gave the following results:

Station 1--Norris Reservoir--February 9, 1960

Melosira (centric diatom) - 11/ml

Station 4--Clinch River--Centers Ferry--February 14, 1960

Synedra (pennate diatom) - 22/ml

Station 4--Emory River--February 14, 1960

Chlamydomonas (green flagellate- 23/ml

Ceratoneis (pennate diatom) - 23/ml

Total 46/ml

Station 5--Tennessee River--Fort Loudoun Reservoir--February 10, 1960

Cyclotella (centric diatom) - 68/ml

Synedra (pennate diatom) - 91/ml

Total 159/ml

TABLE 21

RADIONUCLIDE CONCENTRATIONS OF VARIOUS AQUATIC ANIMALS FROM CLINCH AND TENNESSEE RIVERS

Feb. 9 - 15, 1960

Sample	Ce^{144}-Pr^{144} pc/kg**	Ru^{106}-Rh^{106} pc/kg**	Cs^{137}-Ba^{137m} pc/kg**	Zr^{95}-Nb^{95} pc/kg**	Zn^{65} pc/kg**	Co^{60} pc/kg**	Sr^{90}*** pc/kg**
Snails from Norris Reservoir	---	T	---	---	2170	---	145.
Crayfish from Norris Reservoir	---	---	---	---	---	---	118.
Clam from Clinch River above White Oak Creek	---	T	---	---	T	---	35.8
Turtle from Clinch River, Gallaher Bridge	+*	---	+*	+*	T	---	
Clam shells from below Watts Bar Dam	T	T	T	T	T	---	1070

* (+) values indicate presence of nuclides, but counting efficiency not determined.

** Live weight

*** Sr^{90} values shown only for sample analyzed. Values obtained by radiochemical analyses.

1 pc = 10^{-12} curies.

Station 7--Tennessee River at Chattanooga--February 15, 1960

Chlamydomonas (green flagellate)-	46
Golenkinia (coccoid green alga) -	23
Cryptomonas (pigmented flagellate)	46
Cyclotella (centric diatom) -	114
Melosira (centric diatom) -	68
Asterionella (pennate diatom) -	23
Navicula (pennate diatom) -	46
Synedra (pennate diatom)	114
Total	480

Because of the sparse population of plankton, the size of samples used were not considered valid for weight determinations. The tow samples were also considered inadequate for radionuclide analysis.

F. Filamentous algae and higher aquatic vegetation were extremely scarce except in the Clinch River above the backwater of Watts Bar Reservoir where *Cladophora sp* was abundant on rocks in fast water.

G. Filter Sand from Chattanooga Water Treatment Plant

Gamma spectra of filter sand as collected, after washing, and of two wash waters were obtained. Corresponding nuclide concentrations for these samples are shown in Table 22. The filter of the unwashed sand showed activity due to cerium-144-praseodymium-144, ruthenium-106-rhodium-106, cesium-137-barium-137m, and cobalt-60, with a trace of zirconium-95-niobium-95. In order to determine if this activity could be removed from the sand by a simple back-wash procedure, the sand sample was

TABLE 22

RADIONUCLIDE CONCENTRATIONS OF FILTER SAND AND FILTER SAND WASH-WATER RESIDUE

FROM THE CHATTANOOGA WATER TREATMENT PLANT

Feb. 9 - 15, 1960

Sample	Ce^{144}-Pr^{144} pc/kg*	Ru^{106}-Rh^{106} pc/kg*	Cs^{137}-Ba^{137m} pc/kg*	Zr^{95}-Nb^{95} pc/kg*	Zn^{65} pc/kg*	Co^{60} pc/kg*
Unwashed Filter Sand	330*	5700	T	T	---	100*
Twice Washed Filter Sand	197*	2200*	T	6*	32*	88*
First Wash-Water Residue	14,400**	125**	T	0.8**	---	---
Second Wash-Water Residue	26**	653**	T	---	4**	T

* Dry weight

** pc/liter

1 pc = 10^{-12} curies.

placed in an approximately equal volume of water and slowly stirred for about five minutes. After this preliminary washing the sand was again resuspended in about an equal volume of water and stirred quite rapidly for approximately 20 minutes to see if attrition between sand grains would remove any activity left on the sand after the first washing. This latter spectrum indicated that the activity due to ruthenium, cesium, and cobalt are very firmly attached to the sand particles and would be difficult to remove by mechanical means. The type of fixation, however has not been determined.

The concentration factors given in Table 23 appear to follow the expected food chain relationships, with the highest factors in gizzard shad, a definite plankton feeder, which obtains food close to the nuclide source. The factors for bottom or filter feeders are somewhat lower and for the game fish the lowest.

Table 24 shows the strontium-90 activities of various components of fish collected from White Oak Creek, the Clinch and Tennessee Rivers. Column 5 shows the concentration factors of these various component parts in relation to the concentration of strontium-90 in water on an equal weight basis. Column 6 shows the ratio of strontium-90 in bones to that in flesh, also on an equal weight basis.

These data show that fish concentrate strontium-90 by factors of 10 to 100 with the highest concentrations in the calcareous tissues--bones and scales. The ratios of strontium-90 in bones to that in flesh

TABLE 23

Radionuclide Concentration Factors By Fish In The

Clinch and Tennessee Rivers

$\left[\frac{\text{pc/kg fish}}{\text{pc/liter water}}\right]$

Sample	$Ce^{144}-Pr^{144}$	$Ru^{106}-Rh^{106}$	$Cs^{137}-Ba^{137m}$	Co^{60}
		Station 2		
Gizzard shad	---	10.4	7.4	22.
White bass	---	.8	.8	.5
Sauger	---	.3	.7	---
		Station 3		
White bass	.13	.1	1.5	---
Sauger	---	.6	1.6	---
Gizzard shad	3.2	6.9	44	14
Skipjack herring	---	.9	1.1	---
Carp	---	.5	2.8	---
		Station 4		
Sauger	---	.8	12.	---
Smallmouth bass	---	.7	11.5	---
Smallmouth buffalo	---	.1	8.7	---
Carp	---	.1	13.5	---
Carpsucker	---	1.9	37.0	---
		Station 7		
Buffalo		6.1	---	---

TABLE 24

Sr^{90} Concentration Factors for Various Fish Components

Station (1)	Water Conc. pc/l (2)	Sample (3)	Activity pc/kg Sample (4)	Conc. Factor pc/kg Sample / pc/liter water (5)	Bone / Flesh Ratio (6)
2	2825	White Bass			
		Structure	56	.02	
2	2825	Sauger			
		Structure	16	.005	
3	19.7	White Bass			
		Bone	665	33.8	2.2
		Flesh	298	15.1	
		Scales	635	32.2	
		Sauger			
		Bone	485	24.6	4.2
		Flesh	115	5.8	
		Scales	263	13.4	
		Gizzard Shad			
		Bone	850	43.2	0.6
		Flesh	1365	69.3	
		Scales	1080	54.8	
		Skipjack			
		Scales	162	8.2	
		Carp			
		Bone	1715	87.1	5.0
		Flesh	340	17.3	
		Scales	1080	54.8	
4	5.8	Sauger			
		Bone	155	26.7	2.2
		Flesh	69	12.0	
		Smallmouth Bass			
		Bone	336	57.9	0.7
		Flesh	500	86.2	
		Scales	291	50.2	
		Smallmouth Buffalo			
		Scales	109	18.8	
		Flesh	134	23.1	

TABLE 24 (Continued)

Sr^{90} Concentration Factors for Various Fish Components

Station (1)	Water Conc. pc/l (2)	Sample (3)	Activity pc/kg Sample (4)	Conc. Factor $\frac{\text{pc/kg Sample}}{\text{pc/liter water}}$ (5)	$\frac{\text{Bone}}{\text{Flesh}}$ Ratio (6)
		Carp			
		Bone	808	139.3	2.8
		Flesh	285	49.1	
		Scales	691	119.1	
4	5.8	Carpsucker			
		Bone	1640	283.	1.6
		Flesh	1030	178.	
		Scales	557	96.	
7	4.4	Catfish			
		Bone	665	151.	13.4
		Flesh	49.7	11.3	
				Average	3.6

(Column 6) vary from 0.6 to 13.4, with an average ratio for the nine pairs of samples of 3.6. This is somewhat lower than the value of 10 quoted for humans. (Ref. Handbook 69 or ICRP).

Table 25 lists the amount of activity in the water phase passing Stations 1, 3, 4, 5, 6, and 7 daily. These represent the product of the values reported in Table 2 and the estimated flow of the river at the particular station in liters/day. The dashes do not necessarily indicate zero values, but nuclide concentrations below the detectable level of the instrument used for analysis.

The river flows at Station 1, 3, and 4 were taken to be the average of mean weekly discharges at Norris Dam in February for the years 1939 through 1945; at Station 5 similar discharge values at Loudoun Dam were used; at Station 6 discharge values at Watts Bar Dam were used; and at Station 7 discharge values at Hales Bar Dam were used.*

From Table 25 it will be noted that the cerium-144-praseodymium-144, cesium-137-barium-137m, and cobalt-60 disappear from the water phase during the first fifteen miles of river flow, while the ruthenium-106-rhodium-106 and strontium-90 are retained in the water for a lonter period of time. The total activity values reported at each station do not decrease consistently with distance or time of flow as one might expect in a natural waterway with a constant uptake of these materials by the associated environmental media. In fact terminal values for gross

* The data were taken from the publication "Engineering Data, Tennessee Valley Authority Projects, Technical Monograph No. 55", January 1947.

TABLE 25

Calculated Activity (curies/day) Carried in The Water

Past Each Station Per Day

Station	1	3	4	5	6	7 (Raw water)
Estimated approximate flow in l/day	[1] $1.8\text{x}10^{10}$	$1.8\text{x}10^{10}$	$1.8\text{x}10^{10}$	$5.1\text{x}10^{10}$	$11.1\text{x}10^{10}$	$13.7\text{x}10^{10}$
Curies/day of						
Ce^{144}-Pr^{144}	---	11.25	---	---	---	---
Ru^{106}-Rh^{106}	---	16.95 (48.5)	5.82 (58.2)	---	9.6 (57.7)	53 (88.4)
Cs^{137}-Ba^{137m}	---	0.88	0.50	---	---	---
Co^{60}	---	0.31	---	---	---	---
Sr^{90}	.009	0.35	0.10	0.02	0.166	0.6

amounts of these nuclides are larger than those reported upstream. Such anomalies are probably due to the operation of the man-made controls on these streams at the Watts Bar and Chickamauga Dams and to the methods of collection of the water sample.

There are no man-made controlling fixtures in the Clinch River between Stations 3 and 4 and the samples at these stations were collected by similar methods and at similar depths. If these values are compared (Table 25) a dimunition of total activity for each of the nuclides is shown at the downstream station and the anomalies mentioned previously disappear.

The numbers in parenthesis after the ruthenium-106-rhodium-106 values at Stations 3, 4, 6, and 7 are the gross ruthenium-106-rhodium-106 activities divided by the gross strontium-90 activities at these individual locations. The relative constancy of these ratios indicates that there is little difference in the behavior of these radionuclides in this river system after about six miles of flow.

Table 26 shows the nuclide concentrations calculated for the unwashed filter sand, the two wash waters, and the washed sand from the Chattanooga Water Treatment Plant.

The customary suspension of the sand during backwashing appears to remove very little cerium-144-praseodymium-144 and cobalt-60, and only about 8 per cent of the ruthenium-106-rhodium-106. Laboratory findings show that more vigorous backwashing, (as perhaps when an air

TABLE 26

Activities of Filter Sand And Wash Waters

(Activities in picocuries/sample)

	$Ce^{144}-Pr^{144}$	$Ru^{106}-Rh^{106}$	Co^{60}
Unwashed Sand	212	3675	65
Washed Sand	126	1470	56
First Wash Water	---	280	---
Second Wash Water	89	2300	2
Total Activity in Latter three Samples	215	4050	58
% Recovery	101	110.	112

wash is used) would remove much more of the adsorbed activity because of attrition between the sand grains. This would physically remove the activity tied up with silts or bacterial growths on the sand grains.

Cobalt 13 Organic Matter

GB #12

CLINCH RIVER STUDY

WASTE DISPOSAL SECTION - SEDIMENT STUDIES

APRIL 1960 - SEPTEMBER 1960

In an earlier report[1] the uptake of cobalt by organic matter in sediments was considered. This study was continued in order to understand the behavior of cobalt in solution and to evaluate the use of this nuclide in possibly establishing the role of organic matter in radionuclide uptake. In Table 1 the influence of pH on the hydrolysis of cobalt is shown. The increasing removal of cobalt with increasing pH is to be expected; the reduction observed at pH 10.0 - 9.5 is considered to be due to the dispersion of colloids at these pH. Several pH measurements of water from the Clinch River gave values about 8.5.

To gain more information on the uptake of cobalt by certain minerals, several materials were tested. These results are summarized in Table 2. Arizona Bentonite shows a much higher affinity for cobalt than Wyoming Bentonite which was reported earlier. Other tests have shown that Arizona Bentonite has properties more nearly like vermiculite than Wyoming Bentonite. The much higher K_d reported for vermiculite in this test than in the earlier experiments is attributable to the much finer particle size of the material in Table 2. Structural and steric considerations of vermiculite favor removal of ions such as cobalt.

In Table 3 cobalt removals by several organic materials are included. Note that with increasing contact time organic matter taken from a river sediment removes appreciable quantities of cobalt. It should be mentioned that the final pH of the organic matter increased to 6.8 for the 250 μ

20 JUL 96 10: 4

material and 6.1 for the 840 μ material. Considering the impurities in the sample, the removal is excellent. Other tests using lignite (a material of much lower ion exchange capacity than peat) showed that cobalt is efficiently removed.

These studies, though preliminary in nature, are useful in formulating procedures for ascertaining the radionuclide budget in the Clinch River. In addition to determining the mineral content of the sediments, studies will be made on the organic portions of the sediment. Selected samples which have been assayed for radionuclides will be analyzed for their particle size distribution, ion exchange capacity, radionuclide content after hydrogen peroxide decomposition of organic matter.

Reference

1. A. Sorathesn, G. Bruscia, et al., "Mineral and Sediment Affinity for Radionuclides," ORNL-CF-60-6-93, July 25, 1960.

Table 1. Effect of Solution of pH on the Removal of Cobalt

pH		Per Cent Removal After		
Initial	Final	2 hours	20 hrs	120 hrs
4.0	4.3	0.0	0.0	0.0
6.0	6.9	6.6	7.2	17.7
8.0	8.0	22.4	19.6	19.5
10.0	9.5	9.9	12.7	9.4

Table 2. Cobalt Removal by Several Materials at Selected pH*

Material	Contact Time	Per Cent Removal at		K_d	
		pH 6	pH 8	pH 6	pH 8
BIOTITE	1 hr	8.96	39.10	200	1280
	1 day	10.80	72.31	240	5200
	5 days	11.93	86.81	270	13,100
ILLITE	1 hr	20.82	35.71	530	1110
	1 day	32.10	66.51	950	3990
	5 days	42.38	84.17	1570	10,600
ARIZONA BENTONITE	1 hr	74.08	78.86	5720	7560
	1 day	92.40	87.40	24,300	13,900
	5 days	98.70	90.05	151,800	18,100
VERMICULITE	1 hr	66.29	74.73	3930	5900
	1 day	79.80	92.03	7900	23,100
	5 days	92.86	97.66	26,000	83,500

*0.05 gram material in 100 ml Co^{60} solution.

Table 3. Cobalt Removal by Several Organic Materials and River Sediments.

Material	Particle Size	pH	Per Cent Removal After			K_d After		
			1 hr	20 hrs	120 hrs	1 hr	20 hrs	120 hrs
Peat Moss	> 20 mesh	5.5	95.95	96.92		23,700	31,500	
Peat Moss	< 30 mesh	5.3	97.76	97.94		43,600	47,500	
River Sediment 6.0 - 150	-	8.2	96.94	94.80		31,700	18,200	
River Sediment 7.0 - 450	-	8.2	94.48	96.08		17,100	24,500	
Organic Matter	250 μ	5.5	13.23	40.89	70.17	300	1,380	4,700
Organic Matter	500 μ	5.4	11.88	46.86	84.03	270	1,760	10,500
Organic Matter	840 μ	5.3	10.48	38.73	82.61	230	1,270	9,500

Fish

[illegible]

[illegible] and in March, 1962

Median concentrations of cesium-137, ruthenium-106, cobalt-60, and strontium-90 in flesh, bone and viscera of fish collected in June and December, 1961 and March, 1962 are listed in Tables 1, 2, and 3. Most of these fish were collected with gill nets but for the December, 1961 and March, 1962, trips, some were collected through use of the shocking apparatus operated by Dan Nelson's group at Oak Ridge National Laboratory. The inability to collect the same species of fish on every trip in large enough numbers has made interpretation of the results of radionuclide analyses difficult.

The more obvious differences as shown in Figure 1, such as, accumulation of strontium-90 in bone, cesium-137 in flesh and viscera, cobalt-60 in bone, and ruthenium-106 in bone and viscera, are due to differences in the chemistry of the radionuclides which limit availability, uptake, and accumulation by the different tissues. Variations in uptake due to species differences are caused somewhat by differences in food chains. Other factors, such as, variations in water concentrations and variations in individual fish all have a [illegible] effect on the amount of uptake.

Primarily for the reason that it is difficult to collect fish [illegible] around, an artificial grouping of fish species into bottom-feeders, plankton-feeders and algae-feeders has been made. In Figure 2 is a comparison of some of these fish feeding types from the March, 1962 trip. The bottom-feeders [illegible] are made up of carp and [illegible]. Comparison of median values for these bottom-feeders [illegible] plankton-feeders (gizzard shad) have [illegible]

20 JUL 96. 10: 4

[illegible] of Radionuclides in Fish

Collected from [illegible] and Tennessee Rivers

Species (No.)	Collection Location	Collection Date	Flesh ^{106}Ru	Flesh ^{137}Cs	Flesh ^{60}Co	Flesh ^{90}Sr
			pCi/kg. live weight			
Carp (2)	C[illegible] 14.6	6/61	[illegible]	[illegible]	40	[illegible]
(11)	CRM 14.6	12/61	213	374	75	374
(54)	CRM 14.6	3/62	162	[illegible]	[illegible]	—
(5)	TRM 562.7	6/61	45	[illegible]	[illegible]	[illegible]
(4)	TRM [illegible]	12/61	146	[illegible]	[illegible]	[illegible]
Gizzard Shad (3)	C[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
(1)	C[illegible]	12/61	[illegible]	[illegible]	[illegible]	[illegible]
(21)	C[illegible] 14.6	3/62	[illegible]	[illegible]	[illegible]	—
(7)	TRM [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
(4)	TRM [illegible]	[illegible]	[illegible]	172	[illegible]	[illegible]
Sight-Feeding Fish (1)[a]	C[illegible] 14.6	6/61	0	1,[illegible]	74	[illegible]
(7)	C[illegible] 14.6	12/62	146	[illegible]	[illegible]	101
(13)	C[illegible] 14.6	3/62	[illegible]	[illegible]	[illegible]	—
(2)	CRM 14.6	3/62	[illegible]	[illegible]	[illegible]	—
(3)	C[illegible] 14.6	3/62	[illegible]	[illegible]	[illegible]	—
(1)	T[illegible]	6/61	[illegible]	[illegible]	[illegible]	[illegible]
(4)	T[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bottom-Feeders[b] (4)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
(6)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
(1)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
(7)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

a. [illegible] according to collection, respectively, [illegible] [illegible], largemouth bass, white bass, sauger.

b. Composed of [illegible] and buffalo. These fish have approximately the same concentrations of these radionuclides.

Median Concentration of Radionuclides in Fish Collected from Clinch and Tennessee Rivers

Species (No.)	Collection Locus	Collection Date	Bone Ru^{106}	Bone Cs^{137}	Bone Co^{60}	Bone Sr^{90}
			μμc/kg, live weight			
Carp (2)	CRM 14.6	6/61	316	415	158	9,400
(11)	CRM 14.6	12/61	470	273	418	10,466
(54)	CRM 14.6	3/62	516	216	275	11,847
(5)	TRM 562.7	6/61	170	89	48	2,190
(4)	TRM 538.8	12/61	212	110	57	1,952
Gizzard Shad (3)	CRM 14.6	6/61	465	595	151	10,110
(1)	CRM 14.6	12/61	250	74	144	7,944
(21)	CRM 14.6	3/62	1,328	365	52	4,212
(7)	TRM 562.7	6/61	138	240	170	1,860
(4)	TRM 529.9	6/61	704	218	189	2,350
Sight-Feeders (1)[a]	CRM 14.6	6/61	324	1,041	201	6,764
(7)	CRM 14.6	12/61	356	398	52	1,782
(13)	CRM 14.6	3/62	289	549	21	9,558
(2)	CRM 14.6	3/62	98	112	45	2,515
(3)	CRM 14.6	3/62	211	581	116	5,451
(1)	TRM 562.7	6/61	324	194	5	500
(4)	TRM 538.8	12/61	333	314	34	923
Bottom Feeders (4)[b]	CRM 14.6	6/61	1,230	298	136	11,448
(6)	CRM 14.6	3/62	318	334	285	6,926
(1)	TRM 562.7	6/61	0	5,084	29	890
(7)	TRM 517.9	6/61	399	122	180	1,400

a. Species listed according to collection, respectively, sauger, sauger, largemouth bass, white bass, sauger.

b. Composed of carpsucker and buffalo. These fish have approximately the same concentrations of these radionuclides.

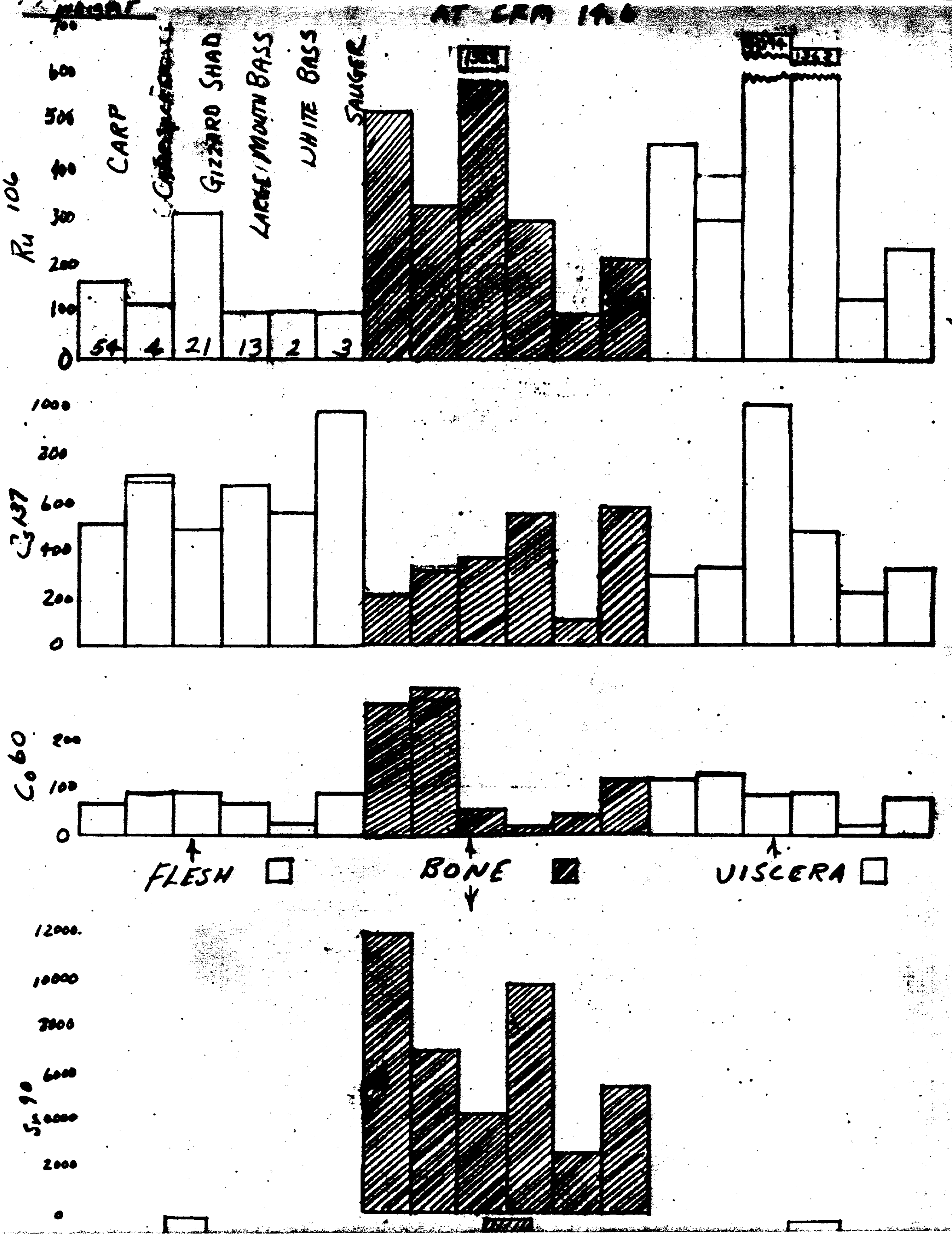
[illegible] Concentration of Radionuclides in Fish

Collected from Clinch and Tennessee Rivers

Species (No.)	Collection Locus	Collection Date	Viscera Ru^{106}	Viscera Cs^{137}	Viscera Co^{60}	Viscera Sr^{90}
			μμc/kg, live weight			
Carp (2)	CRM 14.6	6/61	1,066	244	52	—
(11)	CRM 14.6	12/61	620	232	174	—
(54)	CRM 14.6	3/61	448	296	118	—
(5)	TRM 562.7	6/61	90	358	113	—
(4)	TRM 538.8	12/61	426	71	128	—
Gizzard Shad (3)	[illegible] 14.6	6/61	1,142	3,404	248	—
(1)	[illegible] 14.6	12/61	—	—	—	—
(21)	[illegible] 14.6	3/62	4,004	1,016	84	—
(7)	[illegible] 562.7	6/61	746	[illegible]	203	—
(4)	[illegible]	6/61	[illegible]	281	109	—
Sight-Feeders[a] (1)	CRM 14.6	6/61	143	420	0	—
(7)	CRM 14.6	12/61	456	573	34	—
(13)	CRM 14.6	3/62	1,362	408	[illegible]	—
(2)	CRM 14.6	3/62	126	228	21	—
(3)	CRM 14.6	3/62	233	318	77	—
(1)	TRM 562.7	6/61	200	662	166	—
(4)	TRM 538.8	12/61	266	326	136	—
Bottom-Feeders[b] (4)	CRM 14.6	6/61	1,347	358	130	—
(6)	CRM 14.6	3/62	386	320	127	—
(1)	TRM 562.7	6/61				—
(7)	TRM 517.9	6/61	404	163	127	—

a. Species listed according to collection, respectively, sauger, sauger, largemouth bass, white bass, sauger.

b. Composed of carpsucker and buffalo. These fish have approximately the same concentrations of these radionuclides.



AT CRM 146
CARP
GIZZARD SHAD
LARGE MOUTH BASS
WHITE BASS
SAUGER
Ru 106
54
4
21
13
2
3
Cs 137
Co 60
FLESH
BONE
VISCERA
Sr 90

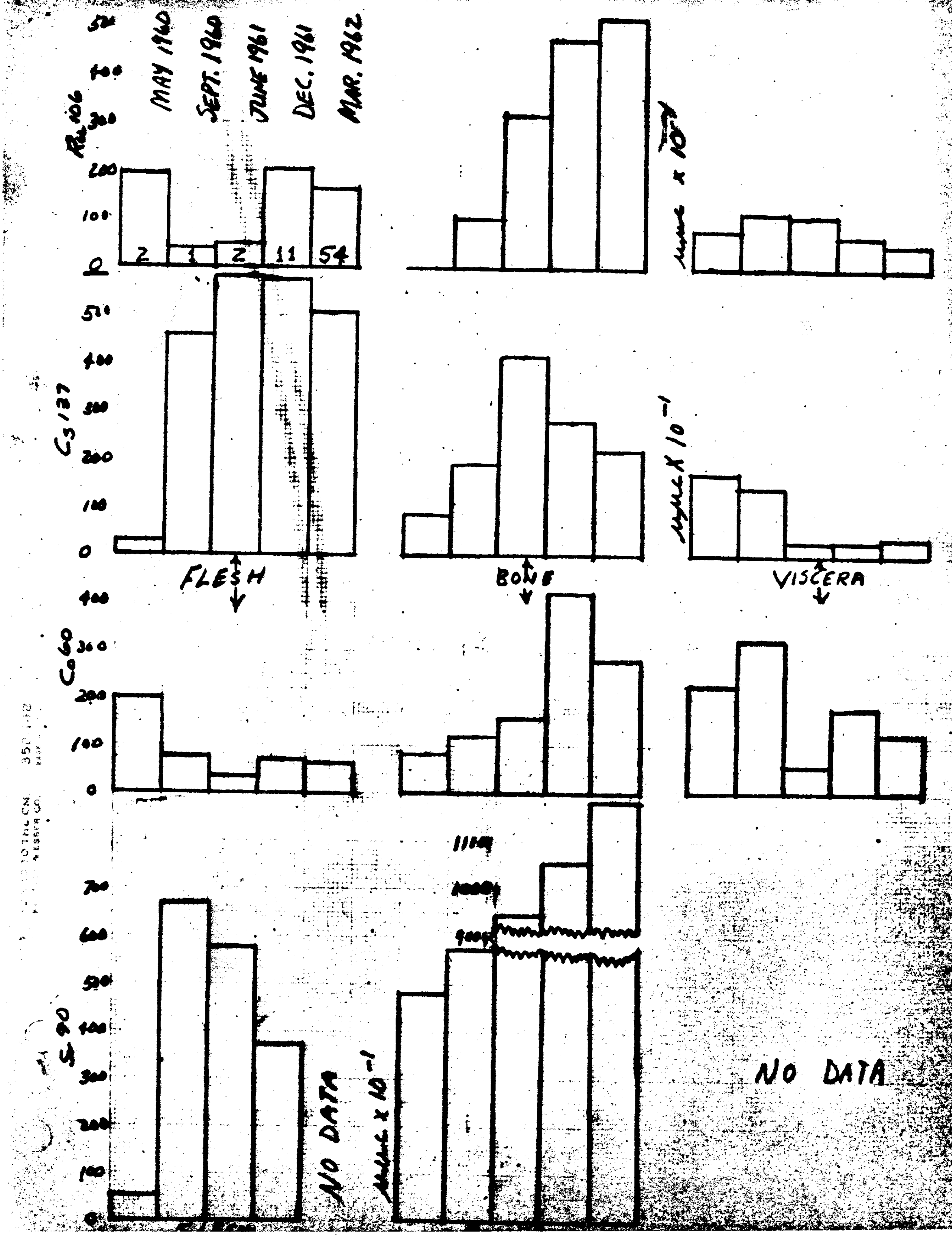
the highest concentrations of ruthenium-106 while the three sight-feeding species show contrasting variations in ruthenium-106 concentrations. The only other apparent observation concerning classification according to feeding habits is the large accumulation of cobalt-60 in the bone of the bottom-feeders.

It is obvious that trying to lump fish together by feeding habits is only an approximation, since species differences cause variation in activity levels. However, some speculation about distribution within the river system has been made. The levels of activity in fish collected different distances downstream from White Oak Creek as summarized for bottom-feeding fish in Status Report No. 3 are an example of this. The effect on activity seems to be primarily dilution but factors like species must have significant effect on the concentration in fish since the change in activity levels does not correspond to a dilution factor.

In Figure 2 are presented data for carp showing the variation in activity levels with time of collection. Also included are carp results for May and September, 1960, which are summarized in Status Report No. 3. The variation in results follows no apparent pattern but this is probably due to sample variation and the fact that water concentrations change so much from day to day.

The accumulation of ruthenium-106 and strontium-90 in bone of carp appear to follow the same pattern. Accumulation of cesium-137 appears to have reached a peak in flesh and remained at this level. Seasonal variation cannot be ascertained from these data due to the lack of continuous and successful sampling.

CARP



MAY 1960
SEPT. 1960
JUNE 1961
DEC. 1961
MAR. 1962
Ru 106
Cs 137
Co 60
Sr 90
2
1
2
11
54
FLESH
BONE
VISCERA
μμc x 10^-1
NO DATA
NO DATA

GB #12

FISH

PROGRESS REPORT NO. 3

SUBCOMMITTEE ON SAFETY EVALUATION

Clinch River Study Steering Committee

December 4, 1963

Introduction

When radioactive material is released to a body of water, there is a complex network of mechanisms by which the material is transmitted from one component, animate or inanimate, to another. At each point in the network or chain of transmission, humans or other life forms may receive some degree of radiation exposure. The probability that human exposure will occur and the degree of such exposure depend, at least, upon interactions within the body of water that includes the contaminants that are released to the water, the habits of people who are likely to be exposed, and control measures used to minimize exposure.

Knowledge of water utilization downstream indicated that the important avenues of exposure resulting from discharge of radioactive fluids to the Clinch River may include: (1) consumption of contaminated water and fish, (2) exposure to contaminated water and bottom sediments during recreational and industrial use of the water, (3) consumption of agricultural produce that may be irrigated with river water, and (4) exposure to build-up of radionuclides in sludge and deposits in water systems utilizing river water.

Estimates have already been made of the dose rate associated with external exposure to contaminated water and bottom sediments, of the potential problems that may result from use of contaminated river water for irrigation purposes, and of the fraction of maximum permissible dosages likely to be received from drinking Clinch River and Tennessee River water.[1, 2] This report includes additional consideration of the dose received by ingestion of known concentrations of radionuclides in drinking water and calculations of internal exposure due to consumption of contaminated fish and external exposure due to build-up of radionuclides in water systems utilizing river water.

Drinking Water

The fraction of MPC_w attained for the case of internal dose was calculated according to recommendations of the ICRP.[3] For a mixture of invariant composition and based on a particular organ, x, the fraction of MPC_w that is attained is given by:

$$\sum_i \frac{P_{wi}}{(MPC)^x_{wi}} \qquad (1)$$

where

P_{wi} = the concentration of the particular radionuclide in water and

$(MPC)^x_{wi}$ = the maximum permissible concentration of the particular radionuclide in water for the organ and individual of interest and for continuous exposure.

The values of P_{wi} are average values, the period of averaging being 1 year according to the recommendations of ICRP, NCRP, and FRC. All MPC_w values used for data relating to the Clinch River are taken as one-tenth of the occupational MPC_w values for continuous exposure. To obtain MPC_w

values relating to the Tennessee River, the MPC_w for continuous occupational exposure has been reduced by a factor of one-hundredth for whole body as critical organ and by one-thirtieth with thyroid, bone, and GI tract as the critical organs. Results of calculations of the fraction of MPC_w in water from the Clinch River and Tennessee River were given in Progress Report No. 2 (ref 4). For the mixture of radionuclides encountered, the estimated exposure to the bone was largest, attaining 0.51 of the MPC_w limit in the Clinch River during 1954. Improvements in waste handling and treatment have reduced the discharge of Sr^{90} whereby the fraction of MPC_w attained has been lowered to approximately 0.05.

If the fraction of MPC_w calculated from equation 1 is multiplied by the appropriate annual dose rate permitted in the particular organ of interest, an annual dose rate is obtained. A careful interpretation of such values is necessary, since the calculated MPC_w only applies to a long-term and stable situation. The MPC_w values are set by the requirement that the dose rate (rems/week) after 50 years of exposure of an adult shall not exceed a recommended limit. During a 50-year exposure period, equilibrium is reached by most of the radionuclides, because their effective half life is short compared to 50 years. However, in the case of Sr^{90}, the allowable annual dose rate is reached only after 50 years of continuous exposure to the MPC_w. For this reason, calculation of actual dose received by ingestion of known concentrations of radionuclides is desirable. As a second interpretation, the calculated dose rate may be considered as the dose that will be received by an adult during the next 50 years due to the exposure with P_{wi}. Actually, the dose delivered after various times following the intake period depend upon the effective half life of the isotope involved.

Because the MPC's which enter into the calculations have been estimated on the basis of so-called "standard man," the dose really represents only that which would be received by a person of physical characteristics and habits resembling standard man. Thus, the doses estimated should be considered as average values for typical adult individuals. Very little is known at the present time concerning differences in metabolic rates or processes of children and adults as they relate to important radionuclides. However, dose correction factors that take into account differences due to intake and organ size can be estimated.[5]

During ingestion of water, the activity present in a critical organ of the body at time, t (after the start of ingestion), can be expressed as[3, 6]

$$Q = f_w RX \int_0^t e^{-\lambda_e t'} \, dt' \qquad (2)$$

where

Q = μc present in critical organ,

f_w = fraction of ingested radionuclide that is retained in the critical organ,[3]

R = rate of intake of water,

X = concentration of radionuclide in water during exposure,

λ_e = effective half life of radionuclide (year), and

t' = a time variable.

By assuming the concentration of a radionuclide in water is the average annual concentration and the rate of water intake is 2.2 liter per day (standard man), equation 2 is integrated over a time period of 1 year giving

$$Q(I)_t = \frac{f_w R \overline{X}_t}{\lambda_e} \left[1 - e^{-\lambda_e} \right] \tag{3}$$

where

$Q(I)_t$ = μc present in the critical organ due to the intake of water during a particular year, t, and

$\overline{X}_t$ = average annual concentration of a radionuclide in water during a particular year, t.

After the exposure period, t, the quantity of radionuclide remaining in the critical organ is given by

$$Q(A)_{t\tau} = Q(I)_t \, e^{-\lambda_e \tau} \tag{4}$$

where

τ = the years after a particular year, t, and $1 \leq \tau \leq n$. Since the quantity of water consumed by an individual is a function of the individual's age, the critical organ burden is also a function of the individual's age. Thus, an intake correction factor, j_γ (where γ is the individual's age during a particular intake period), must be applied to equations 3 and 4. For example, assume an individual of age $\gamma = 10$ began to consume contaminated water at the beginning of year, t = 1, the critical organ burden of a particular radionuclide each year for a period of 3 years would be determined as follows:

Period	Body Burden (μc)	
t = 1	$j_{10}Q(I)_1$	
t = 2	$j_{11}Q(I)_2 + j_{10}Q(A)_{11}$	
t = 3	$j_{12}Q(I)_3 + j_{10}Q(A)_{12} + j_{11}Q(A)_{21}$	(5)

The dose received by the critical organ during a particular exposure year, t, is

$$D(I)_t = \frac{MPD}{qf_2} \int_o^t Q dt' \qquad (6)$$

where

MPD = the maximum permissible dose rate to a particular organ and

$qf_2 = \frac{MPC_w \, R \, f_w}{\lambda_e} \left[1 - e^{-\lambda_e 50} \right]$, the fraction of radionuclide in the critical organ after 50 years of continuous exposure.

By substituting equation 2 in equation 6 and integrating over an exposure period of 1 year, the dose received by the critical organ during a particular exposure year, t, is

$$D(I)_t = \frac{MPD \, g_t}{1 - e^{-\lambda_e 50}} \left[1 - \frac{1 - e^{-\lambda_e}}{\lambda_e} \right] \qquad (7)$$

where

$g_t = \frac{\overline{X}}{MPC_w}$, the fraction of MPC_w in water during a particular year, t.

After the exposure period, t, the critical organ will continue to be irradiated by the radionuclide retained from the exposure period. The length of time for such residual exposure depends on the effective half life of the radionuclide. The dose after exposure is given by

$$D(A)_{t\tau} = \frac{MPD \, g_t \, \lambda_e}{1 - e^{-\lambda_e 50}} \int_o^t e^{-\lambda_e t'} dt' \int_{\tau-1}^{\tau} e^{-\lambda_e t''} dt'' \qquad (8)$$

where

t" = a time variable.

Integration of equation 8 over an exposure period of 1 year and post exposure period, τ, gives

$$D(A)_{t\tau} = \frac{MPD\ g_t \left[1 - e^{-\lambda_e}\right]}{\lambda_e \left[1 - e^{-\lambda_e 50}\right]} \left[e^{-\lambda_e(\tau-1)} - e^{-\lambda_e \tau}\right] \tag{9}$$

The total dose received by a particular critical organ due to a particular radionuclide after a number of years of exposure is then the sum of equations 7 and 9. A dose correction factor must be applied to equations 7 and 9 to account for differences in the intake and organ size of the individuals under consideration. The dose correction factor is

$$h_\gamma = \frac{R_\gamma / M_\gamma}{R_{sm} / M_{sm}} \tag{10}$$

where

R_γ = the rate of water intake of an individual of age, γ,

R_{sm} = the rate of water intake of standard man,

M_γ = the weight of the critical organ of an individual of age, γ, and

M_{sm} = the weight of the critical organ of standard man.

For an individual of age, $\gamma = 10$, who began to consume contaminated water at the beginning of year, $t = 1$, the dose received each year for a period of 3 years would be determined as follows:

Period	Body Burden (μc)
$t = 1$	$h_{10}\ D(I)_1$
$t = 2$	$h_{11}\ D(I)_2 + h_{10}(M_{10}/M_{11})\ D(A)_{11}$
$t = 3$	$h_{12}\ D(I)_3 + h_{10}(M_{10}/M_{12})\ D(A)_{12} + h_{11}(M_{11}/M_{12})\ D(A)_{21}$ (11)

A code was developed for Control Data 1604 that permits machine computation of critical organ burdens and dose received. A final dose evaluation, taking account of all known factors that might affect the result is not available at this time. The code was run under the following assumptions:

1. Individuals of ages 1 through 18 and standard man drink untreated water from the Clinch River at mile 14.5 (the neighborhood of the controlled area of ORNL). They continue to drink water from this source through 1961, following which water is obtained from an uncontaminated source.
2. Intake and skeleton mass may vary with age as previously indicated. Thus all water taken into the body in foods or other form is assumed equally contaminated.
3. The per cent of total activity due to Sr^{90} in 1944-1948 is the same as that for the period of 1949-1958.
4. All other factors that might effect the results are negligible.

The relative annual dose rates were computed and are shown in Fig. 1, normalized to the maximum individual dose found; that is, the dose to the 14 year old. The differences in dose rate are attributed to differences in intake and size of the skeleton. Unquestionably, refinement of these preliminary calculations is necessary before a dose evaluation can be made.

UNCLASSIFIED
ORNL-DWG 63-1244

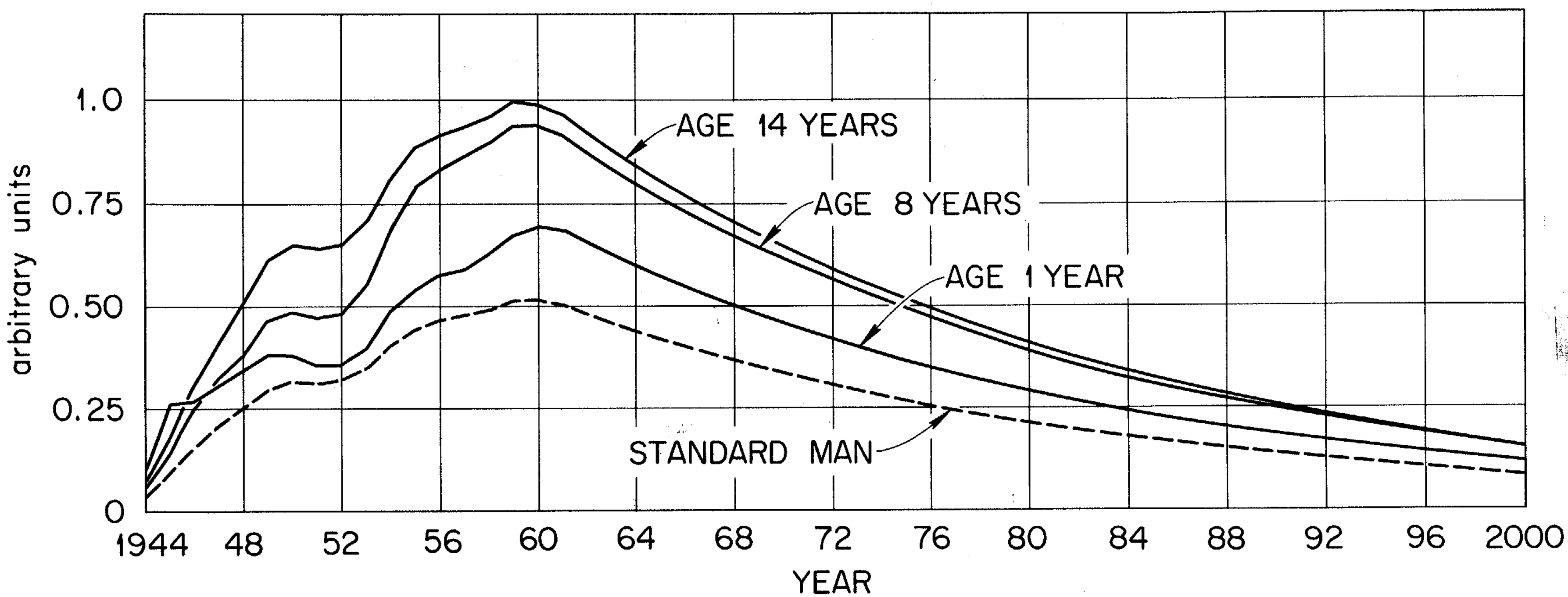


Fig. 1 Dose to Skeleton of Males.

Contaminated Fish

Fish which feed in the Clinch River and Tennessee River downstream of White Oak Creek assimulate some of the radionuclides that are released to the river system. Since fish is a staple of man's diet, radionuclides present in the fish will contribute to the total dose received by man. Parker has shown that a catastrophic release of radionuclides from the biota of the Clinch River system is quite unlikely; the total inventory of radionuclides in the biota is estimated to be less than 1 curie.[7]

The data on radionuclide concentration in fish, used to estimate the dose that man may receive, was developed by the Subcommittee on Aquatic Biology, Clinch River Study Steering Committee.[8-13] Fish were collected during various seasons for the period of 1960 to 1962 and were processed to approximate, insofar as possible, normal human utilization.[9, 13] Bottom feeders (carp, carpsucker, and buffalo) were processed either by grinding the flesh and bones together (total fish analyses) or by removing the flesh after cooking (flesh analyses) and sight feeders (white crappie, bluegill, white bass, large mouth bass, sauger, and drum) were processed by removing the flesh after cooking. For this analysis, catfish are included with the sight feeders, since only the flesh of the catfish was processed. Another fish sampling program was completed May 1963, but analytical results were not available for inclusion in this report.

Not all species of bottom feeders and sight feeders were collected with each sampling program; the number of a particular species collected varied. Therefore, for this analysis, all bottom feeders collected are considered as one sample; sight feeders were handled in similar manner. This assumption precludes any differences in fish due to the time of collection. That is, information on seasonal variation of such factors as feeding rates and water content of the flesh and their effect on radionuclide concentrations is unavailable and cannot be considered in the calculations.

Results of analyses of fish collected from the Clinch River and Tennessee River are listed in Tables 1 and 2, respectively. Average values are given for the four principal nuclides detected (Sr^{90}, Cs^{137}, Ru^{106}, and Co^{60}); variation of the averages is indicated by the standard error of the mean. Standard errors do not appear where fish were composited before analyses. Bottom feeders are listed by species, since information is available on the total quantities of these fish harvested commercially from Watts Bar Reservoir and from East Tennessee (Table 3). Information on sight feeders harvested is meager in comparison and does not warrant analyses by species. Only sport fishing takes place on the Clinch River.

Average values are observed to vary by factors ranging from about 2 to 5 between fish types from the same river; similar variations occur between fish of the same type but from the two rivers. A peculiar difference is noted in Sr^{90} concentrations in sight feeders; the average concentration in Tennessee River fish is about 50% larger than Clinch River fish. At present there is no explanation for these differences. Four carpsuckers, collected at Clinch River Mile 19.6, contained sufficient radionuclides to audioradiograph. This is typical of fish that have spent considerable time in White Oak Creek (or White Oak Lake).[14] Inclusion of these fish in the analysis can be seen to increase significantly the average concentration of radionuclides.

An estimate is made of man's intake of radionuclides by assuming an annual rate of fish consumption of 37 lb.[15] This rate of fish consumption

Table 1. [illegible] of Radionuclides in Clinch River Fish
([illegible]/kg fresh weight)

				Ru^{106}		[illegible]	
Flesh	[illegible]	[illegible]	[illegible]	Flesh	Total[a]	Flesh	[illegible]
500 ± [illegible]	[illegible]	[illegible]	960 ± [illegible]	(69) 170 ± 18	(59) 290 ± 78	(67) 66 ± 6.1	[illegible]
540 ± 190	[illegible]	(128) [illegible]	(37) 610 ± 65	(88) 120 ± 30	(37) 56 ± 16	(88) 190 ± 19	[illegible]
[illegible]	[illegible]	(5) [illegible]	(30) [illegible]	(5) 110 ± 30	(30) 150 ± 30	(5) 76 ± 21	[illegible]
[illegible]	[illegible]	[illegible] 500 ± [illegible]		[illegible]		(127) [illegible] ± 11	[illegible]

[illegible] also included.

[illegible]

Fish Species		Flesh
Carp	(17)[b]	500 ± 1[illegible]
Carpsucker	(18)	540 ± 190
Buffalo	(3)	240 ± 8[illegible]
Sight Feeders[c]	(109)	1[illegible]

[a]Total fish sampl[illegible]

[b]Parenthetical n[illegible]

[c]Sight feeders i[illegible]

[d]Includes four ca[illegible]

Table 2. Concentration of Radionuclides in Flesh of Tennessee River Fish
($\mu\mu$c/kg fresh weight)

Fish Species	Sr^{90}	Cs^{137}	Ru^{106}	Co^{60}
Carp	(13)[a] 120 ± 33	(14) 180 ± 55	(14) 80 ± 27	(14) 71 ± [illegible]
Carpsucker	(10) 99 ± 28	(10) 130 ± 27	(10) 69 ± 23	(10) 62 ± [illegible]
Sight Feeders[b]	(24) 250	(24) 170	(24) 48	(24) 46

[a]Parenthetical values are number of fish analyzed.

[b]Sight feeders include white crappie, bluegill, white bass, largemouth bass, sauger, and drum; catfish also included.

Table 3. Commercial Fish Harvest from Watts Bar Reservoir and East Tennessee (pounds fresh weight)

Location	Carpsucker	Carp	Smallmouth Buffalo
Watts Bar Reservoir	15,600	23,700	161,000
East Tennessee	61,700	135,000	327,000
Fish Dilution Factor[a]	3.95	5.70	2.03

[a]Fish dilution factor = $\frac{\text{pounds of East Tennessee fish}}{\text{pounds of Watts Bar fish}}$.

applies to commercial fishermen and, as a result, would estimate the intake of an admittedly high exposure group. Data on the quantity of specific types of fish consumed and method of preparation is not available. Thus calculations made are based on the annual consumption of 37 lb of bottom feeders, considering both the total fish and the flesh, and consumption of 37 lb of sight feeders, considering only the flesh. The fraction of the various species of bottom feeders caught is assumed to be distributed according to commercial harvests from Watts Bar Reservoir. Estimates of the annual intake of specific radionuclides by consuming Clinch River or Tennessee River fish are given in Tables 4 and 5, respectively. A very noticeable increase in Sr^{90} intake is observed when consumption of bottom feeders (total fish) is considered. This significantly larger intake is due to the concentration of Sr^{90} by the bones of the fish, all of which are assumed to be eaten. Consumption of 37 lb of "fishburgers" each year is certainly an overestimate and unnecessarily conservative. However, without better data of fish consumption, it is impossible to arrive at a more reasonable value of intake.

Radionuclide intake by the general population is likely to be influenced by all fish harvested in East Tennessee, in addition to the differences in radionuclide content among species of bottom feeders. Applying the fish dilution factor (bottom feeders) for East Tennessee fish (Table 3), annual intakes were recalculated and results are given in Tables 4 and 5. A significant reduction in radionuclide intake is observed, ranging from factors of about 2 to 4.

A maximum permissible intake (MPI) is calculated by assuming a daily intake of 2.2 liters of water containing the maximum permissible concentration (MPC) of the radionuclide of interest. Values used for MPC are

Table 4. Estimated Annual Intake of Radionuclides by Assumed Consumption of Clinch River Fish
(10^{-3} μc/year)

	[illegible]		Cs^{137}		Ru^{106}		[illegible]	
	Flesh	[illegible]	Flesh	Total[a]	Flesh	Total[a]	Flesh	[illegible]
Bottom Feeders[b]	4.9 ± 1.3	[illegible] (88)	9.0 ± 1.4	10 ± 1.3	2.0 ± 0.44	2.7 ± 0.54	1.3 ± 0.28	0.58 ± 0.094
Bottom Feeders[c]	1.9 ± 0.60	7.6 ± 0.83 (8.9)	3.7 ± 0.64	4.4 ± 0.19	0.81 ± 0.21	1.1 ± 0.25	0.58 ± 0.044	0.24 ± 0.061
Sight Feeders[d]	3.0 ± 1.4		11 ± 2.6		2.0 ± 0.54		0.38 ± 0.19	

[a]Total fish consists of flesh and bone.

[b]Bottom feeders include carp, carpsucker, and buffalo.

[c]Intake adjusted by fish dilution factor, Table 3.

[d]Sight feeders include white crappie, bluegill, white bass, largemouth bass, sauger, and drum; catfish also included.

[e]Parenthetical values include four carpsuckers (composited) collected at CRM 19.6.

[redacted]

Table 5. Estimated Annual Intake of Radionuclides by Assumed Consumption of Flesh of Tennessee River Fish
(10^{-3} μc/year)

Fish Species	Sr^{90}	Cs^{137}	Ru^{106}	[redacted]
Bottom Feeders[a]	1.9 ± 0.38	2.7 ± 0.59	1.3 ± 0.31	[redacted]
Bottom Feeders[b]	0.39 ± 0.075	0.53 ± 0.11	0.26 ± 0.062	[redacted]
Sight Feeders[c]	4.3	2.8	0.81	1.1

[a]Bottom feeders include carp and carpsucker.

[b]Intake adjusted by Fish Dilution Factor, Table 3.

[c]Sight feeders include white crappie, bluegill, white bass, largemouth bass, sauger, and drum; catfish also included.

[redacted]

discussed at length elsewhere.[16] Using the estimated intakes (Tables 4 and 5), it is possible to calculate the fraction of MPI attained for the various critical organs as a result of eating contaminated fish (Tables 6 and 7). Estimates indicate that bone of the postulated high exposure group may receive the largest dose; on the average, 28 to 34% of the MPI may be attained as a result of consuming bottom feeders (total fish) from the Clinch River. Strontium-90 is responsible for essentially the entire bone dose.

Considerably more information would be required to estimate the dose received due to past events. For example, desired information would include at least: (1) rate of transfer of radionuclides from water to fish (flesh and bone) as a function of radionuclide and stable element concentration, fish age, and season of the year; (2) rate of transfer of radionuclide from bone to flesh while cooking; and (3) type and quantity of fish consumed, method of fish preparation, and dietary habits of individuals as a function of age. Current research suggests that the concentration of Sr^{90} in the flesh of white crappie reaches equilibrium rapidly with the water.[17] Such information lends itself to answering, in part, the questions raised by (1) above and extension of these studies will enhance the ability to estimate doses to man due to past events.

An interesting calculation is made based on the Sr^{90} content of the four carpsuckers previously mentioned. The combined weight of flesh and whole fish (flesh and bone) for the four carpsuckers was 0.51 kg and 0.85 kg, respectively; the Sr^{90} concentration of flesh was 500 μμc/kg and of whole fish was 4300 μμc/kg. An individual eating the four fish could have attained 0.3% of MPI (bone) from the flesh and 44% of MPI (bone) from

[redacted]

Table 6. Estimated Percentage of MPI That Man May Attain By Consuming Clinch River Fish

Fish Species	Critical Organ			
	Bone	Total Body	GI Tract	Thyroid
Bottom Feeders[a] (flesh)	6.1 ± 1.6	1.5 ± 0.39	0.072 ± 0.0081	0.38 ± 0.072
Bottom Feeders[a] (total[b])	28 ± 4.5 (34)[e]	7.1 ± 1.2 (8.6)	0.14 ± 0.014 (0.15)	1.[redacted]
Bottom Feeders[c] (flesh)	2.4 ± 0.75	0.61 ± 0.19	0.05 ± 0.0039	0.[redacted]
Bottom Feeders[c] (total)	9.5 ± 1.1 (12)	2.4 ± 0.35 (2.9)	0.053 ± 0.0047 (0.0058)	0.48 ± 0.051 (0.57)
Sight Feeders[d] (flesh)	3.8 ± 1.7	1.0 ± 0.44	0.071 ± 0.012	0.31 ± 0.080

[a]Bottom feeders include carp, carpsucker, and buffalo.

[b]Total fish consist of flesh and bone.

[redacted] by Fish Dilution Factor, Table 3.

[redacted] include white crappie, bluegill, white bass, largemouth [redacted] catfish also included.

[redacted] values include four carpsuckers (composited) collected at CRM 19.6.

Table 7. Estimated Percentage of MPI That Man May Attain By Consuming Flesh of Tennessee River Fish

Fish Species	Critical Organ			
	Bone	Total Body	GI Tract	Thyroid
Bottom Feeders[a]	7.2 ± 1.4	6.2 ± 1.2	0.11 ± 0.014	0.55 ± 0.084
Bottom Feeders[b]	1.5 ± 0.28	1.3 ± 0.24	0.021 ± 0.0026	0.11 ± 0.017
Sight Feeders[c]	16	14	0.11	0.[illegible]

[a]Bottom feeders include carp and carpsucker.

[b]Intake adjusted by Fish Dilution Factor, Table 3.

[c]Sight feeders include white crappie, bluegill, white bass, large-mouth bass, sauger, and drum; catfish also included.

the whole fish. Although such an event is unlikely, it seems appropriate to reduce further the probability of its occurrence. Such reduction is possible by preventing fish from leaving the controlled area of White Oak Lake and preventing fish from feeding in the stretch of White Oak Creek extending from White Oak Dam to the Clinch River.

Radionuclide Concentration in Water Systems

The presence of radionuclides in the raw water entering a water treatment plant may create, through processes of concentration, an external or internal dose problem. Three water systems using Clinch River water as a source of supply were investigated. The Oak Ridge Water Plant has its raw water intake at CRM 41.5, well above the confluence of White Oak Creek and the Clinch River. The other two water treatment plants - the Sanitary Water Plant serving the Oak Ridge Gaseous Diffusion Plant (ORGDP) and that serving the Kingston Steam Plant - have water intakes at CRM 14 and CRM 3, respectively. The water treatment plants are basically similar, differing only in design details. Treatment processes include: prechlorination for algae control; coagulation using alum, soda ash (as dictated by raw water alkalinity), and occasionally coagulant aids, for turbidity removal; settling; filtration (either sand or anthracite media); and post chlorination for disinfection. Activated carbon is used when taste and other problems occur. Water used in boilers is treated further by zeolite softeners.

The investigation consisted of external radiation surveys, using a scintillation-type survey meter (calibrated with radium) and collection of samples of sludge from settling basins, condensers, hot water heaters, boilers, air conditioners, and an elevated tank, samples of sediment from filters and cores of filter media, and samples of zeolite softener regenerant, as well as the softener media. Results of sample analyses are incomplete and will be reported at a later date.

At the time of the surveys, various amounts of water had been treated since the last time settling basins had been cleaned or filters backwashed (Table 8). Thus, there was variation in the amount of sludge accumulated in the settling basins or sediment accumulated on the filters. Results of the external radiation survey are summarized in Table 9. Generally there was little difference noted in dose rates at different units of the plants. Any increase in dose rate above background levels (referenced to the Oak Ridge Water Treatment Plant) was, with one exception, undetectable. At a distance of 2 in. above a partially drained filter at the Kingston Steam Plant supply, a dose rate of 0.021 mr/hr was detected. The dose rate remained the same after the filter was backwashed. It is likely that the anthracite media of the filter is to some extent concentrating radionuclides by ion exchange; this is currently being investigated by laboratory studies. The dose rate above the filters (0.015 mr/hr) of this supply is also influenced by the natural radioactivity present in the shale-block used for construction of the building walls.

[redacted]

Table 8. Operational Data of Water Treatment Plants

System	Volume Through[a] Flocculator and Settling Basin (gal)	Volume Through[a] Filter (gal)	Sludge in Settling Basin (cu ft)	Plant Capacity (gal/day)
Oak Ridge Water Plant	1.1×10^9	1.8×10^6	2×10^4	22 [redacted]
ORGDP	5.4×10^8	4.5×10^6	6×10^3	4 [redacted]
Kingston Steam Plant	1.9×10^6	3.7×10^5	----	5.7 [redacted]

[a]Volume through flocculator, settling basin, and filter since last cleaned.

[redacted]

Table 9. Measurements of Ionizing Radiation In Water Treatment Plants (mr/hr)[a]

System	Ground Surface	Flocculator	Settling Basin	6 in. Above Water in Settling Basin	Filter
Oak Ridge Water Plant	0.016	0.013	0.012	0.0097	[illegible]
ORGDP	0.017	0.011	0.012	0.0098	[illegible]
Kingston Steam Plant	0.015	0.0085	0.0087	----	[illegible]

[a]All measurements (except as noted) were made 3 ft above the walking surface of the particular component of the treatment plant.

References

[1] Progress Report No. 2 by Subcommittee on Safety Evaluation to Clinch River Study Steering Committee, February 6, 1963 (unpublished).

[2] K. E. Cowser, W. S. Snyder, and M. J. Cook, "Preliminary Safety Analysis of Radionuclide Release to the Clinch River," Proceedings of Conference on Transport of Radionuclides in Fresh Water, January 30, 31, and February 1, 1963, Austin, Texas, U. S. Atomic Energy Commission, Washington, D. C., p 17-39, TID-7664 (July 1963).

[3] Report of Committee II on Permissible Dose for Internal Radiation, International Committee on Radiological Protection, Publication 2, Pergamon Press, London, 1959.

[4] Progress Report No. 2 by Subcommittee on Safety Evaluation to Clinch River Study Steering Committee, February 6, 1963, p 25 (unpublished).

[5] Ibid., p 18-24.

[6] Harry Levin, "Some Aspects of Inhalation Dose Calculation from Single Exposures," Health Phys. **9**, 41-44 (1963).

[7] F. L. Parker, "Clinch River Studies," Proceedings of Conference on Transport of Radionuclides in Fresh Water, January 30, 31, and February 1, 1963, Austin, Texas, U. S. Atomic Energy Commission, Washington, D. C., p 161-181, TID-7664 (July 1963).

[8] A. G. Friend *et al.*, Fate of Radionuclides in Fresh Water Environments: Progress Report No. 2, Clinch and Tennessee Rivers, February 9-15, 1960, interim report to Clinch River Study Steering Committee, Sept. 1960 (multilithed, 1962).

[9] A. G. Friend *et al.*, Fate of Radionuclides in Fresh Water Environments: Progress Report No. 5, Clinch and Tennessee Rivers, May 15-30, 1960, interim report to Clinch River Study Steering Committee, Oct. 1961 (multilithed, 1962).

[10] A. G. Friend *et al.*, Fate of Radionuclides in Fresh Water Environments: Progress Report No. 6, Clinch and Tennessee Rivers, September 19-30, 1960, interim report to Clinch River Study Steering Committee, Oct. 1961 (multilithed, 1962).

[11] D. B. Porcella, Data on Fish Collected in June and December 1961 and March 1962 (personal communication, May 8, 1963).

[12] S. I. Auerbach, Chairman, et al., Progress Report No. 1, Subcommittee on Aquatic Biology, copies submitted to Clinch River Study Steering Committee, April 26, 1962 (unpublished).

[13] S. I. Auerbach, Chairman, et al., Progress Report No. 2, Subcommittee on Aquatic Biology, copies submitted to Clinch River Study Steering Committee, Feb. 6, 1963 (unpublished).

[14] R. E. Martin, S. I. Auerbach, and D. J. Nelson, Growth and Movement of Smallmouth Buffalo, Ictiobus Bubalus (Rafinesque), in Watts Bar Reservoir, Tennessee, ORNL-3530.

[15] P. Bryan and C. E. White, "An Economic Evaluation of the Commercial Fishing in the T.V.A. Lakes of Alabama During 1956," Proceedings of the Twelfth Annual Conference Southeastern Association of Game and Fish Commissioners, 1958, p 128-132.

[16] Progress Report No. 2 by Subcommittee on Safety Evaluation to Clinch River Study Steering Committee, February 6, 1963, p 24 (unpublished).

[17] R. J. Morton et al., Status Report No. 4 on Clinch River Study, Clinch River Study Steering Committee, ORNL-3409 (Sept. 11, 1963).

R. M. Richardson

GB#12

PROGRESS REPORT NO. 4 (FINAL)

Subcommittee on Water Sampling and Analysis
Clinch River Study

December 15-16, 1964

IDENTIAL
TO
Churchill et al
1965
Supplement #1

PROGRESS REPORT NO. 4 (FINAL)

Subcommittee on Water Sampling and Analysis

Clinch River Study

Presented at the meeting of the Clinch River Study Steering Committee

Oak Ridge, Tennessee

December 15-16, 1964

CONTENTS

ILLUSTRATIONS

PROGRESS REPORT NO. 4 (FINAL)

Subcommittee on Water Sampling and Analysis
Clinch River Study

December 15-16, 1964

Purpose of Work

The basic purpose of the work of the Subcommittee on Water Sampling and Analysis is to collect and interpret such information concerning radionuclides suspended and/or dissolved in the waters of the surface streams downstream from Oak Ridge, Tennessee, as will assist the Clinch River Study Steering Committee in pursuing the basic purposes of the entire study, namely, "(1) to determine the fate of radioactive materials currently being discharged to the Clinch River, (2) to determine and understand the mechanisms of dispersion of radionuclides released to the river, (3) to evaluate the direct and indirect hazards of current disposal practices in the river, (4) to evaluate the over-all usefulness of the river for radioactive waste disposal purposes, and (5) to recommend long-term monitoring procedures."

Included as part of the work of the subcommittee is the determination of the mineral quality of the surface waters involved in the over-all study.

Method of Study

General--The general plan of the study involved systematic collection and analysis of water samples at selected sampling stations. Daily subsamples of water, the individual volumes of which at each station (except at Loudon) were proportioned to the volumes of daily streamflow passing that particular station, were composited weekly for analysis (monthly for most mineral analyses). Such analyses provided the mean flow-proportioned concentration of each radionuclide of interest passing each station each week. By combining this mean concentration with the total flow of water passing the station during each week, the total load, in curies, of each radionuclide passing the station was determined. The cumulative load of each radionuclide at each station was plotted progressively with time. The mass curves so produced reveal on comparison, one with another, the quantitative loss (by sedimentation, biological uptake, etc.) or gain (from fallout on the watershed) of this particular radionuclide between successive downstream stations.

The Centers Ferry sampler malfunctioned (see Progress Report No. 3, of the Subcommittee on Water Sampling and Analysis, page 27) during September through November 1961. This malfunction possibly affected the suspended-sediment results for all radionuclides. The degree to which the results are affected is dependent upon the proportion of a given radionuclide associated with the suspended solids.

Sampling Stations--Sampling stations used in the study are located as follows, and as shown in figure 1:

1. Clinch River at Oak Ridge water plant--Clinch River mile 41.5
2. White Oak Creek at White Oak Dam, mile 0.6
3. Clinch River at Gallaher Bridge--Clinch River mile 14.6
4. Clinch River above Centers Ferry--Clinch River mile 5.5
5. Tennessee River at Loudon, Tennessee--Tennessee River mile 591.8
6. Tennessee River at Watts Bar Dam--Tennessee River mile 529.9
7. Tennessee River at Chickamauga Dam--Tennessee River mile 471.0

Period of Sampling--Except for the station at Gallaher Bridge, sampling was begun in November 1960 and extended through November 1962. At Gallaher Bridge, sampling was begun on January 8, 1962, and was discontinued at the end of November 1962.

Sampling Procedures--Sampling procedures at each sampling station have been explained in detail in previous progress reports.

Radiological Determinations--The radionuclides of primary importance in the Clinch River Study, in the order named, are strontium-90, cesium-137, cobalt-60, and ruthenium-106. Consequently, determinations were made of concentrations and total loads of these radionuclides. All radiological determinations in this study have been made by the U. S. Public Health Service, Cincinnati, Ohio.

Details of sample preparation and analysis have been explained in previous progress reports.

Stream Discharges--The necessary data on streamflows at the five upstream sampling stations have been provided by the U. S. Geological Survey, through the cooperation of its Tennessee District. Discharges at Watts Bar and Chickamauga Dams have been supplied by TVA. (See plotted streamflow data in figures 2 and 3.)

Mineral Analyses--All mineral analyses were made in Nashville, Tennessee, by the staff of the Tennessee Stream Pollution Control Board. Methods used and results obtained have been included in previous progress reports.

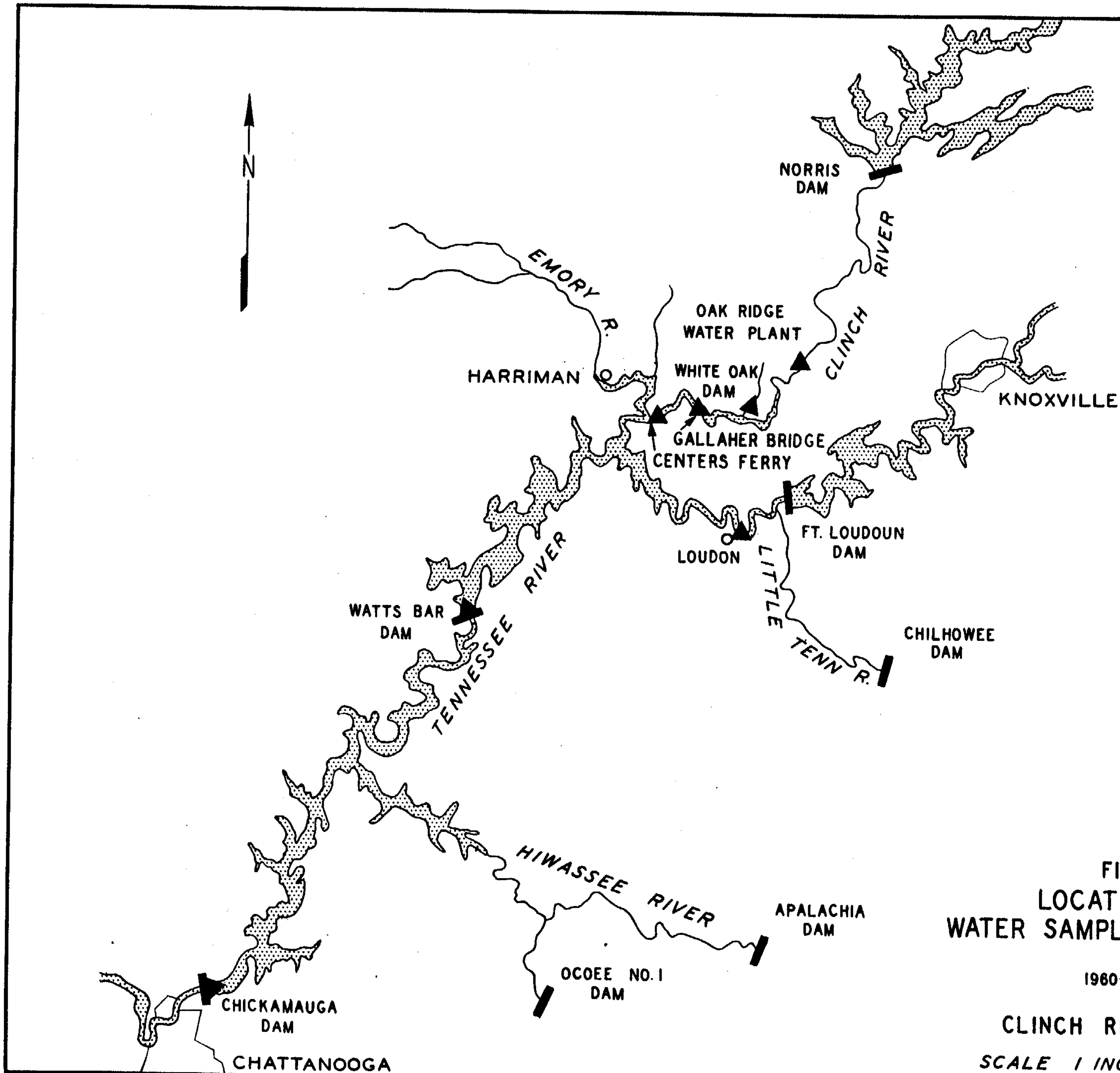
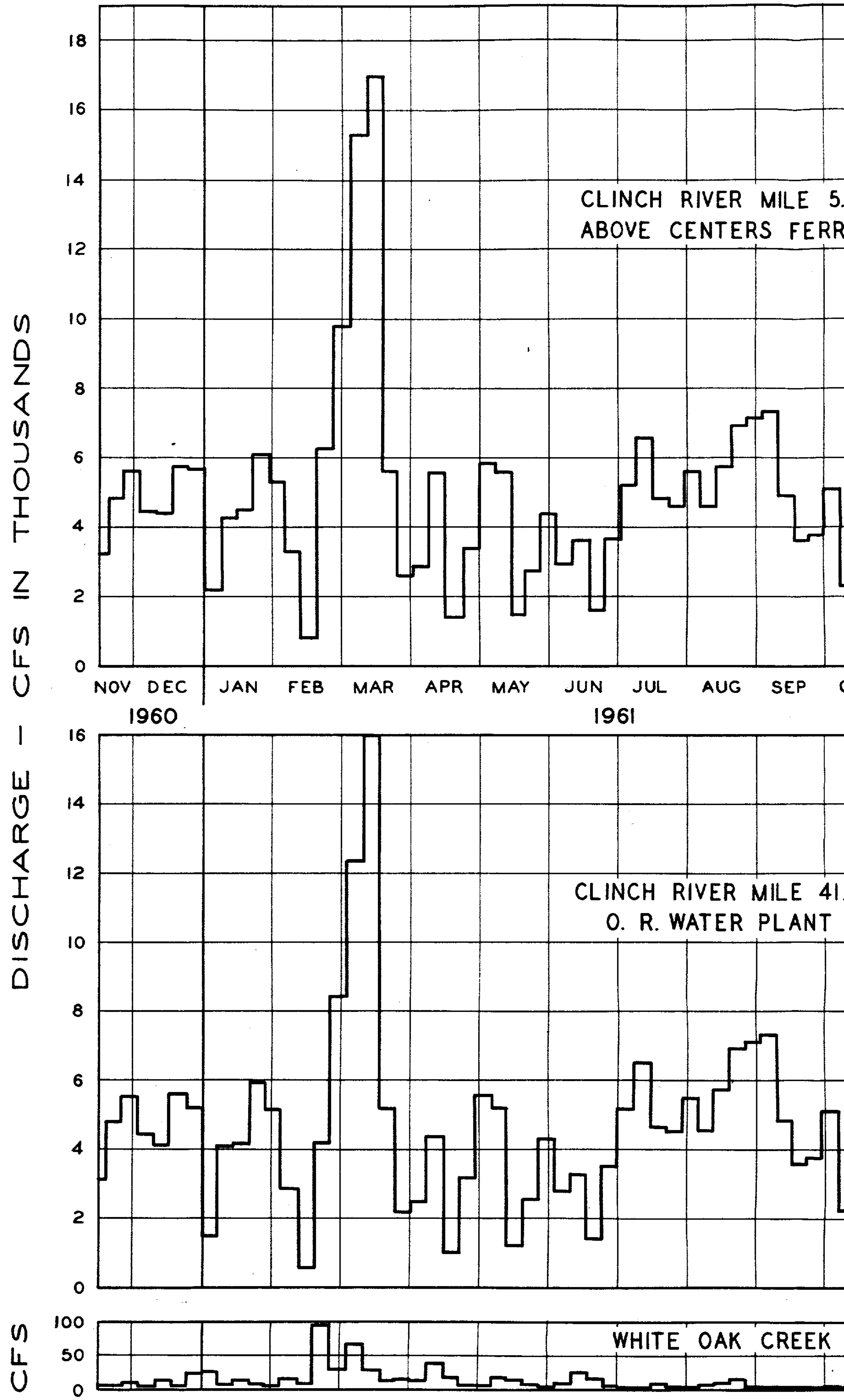


FIG. 1
LOCATION OF
WATER SAMPLING STATIONS

1960-1962

CLINCH RIVER STUDY

SCALE 1 INCH = 14 MILES


DISCHARGE - CFS IN THOUSANDS
CLINCH RIVER MILE 5.
ABOVE CENTERS FERR
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
1960
1961
CLINCH RIVER MILE 41.
O. R. WATER PLANT
CFS
WHITE OAK CREEK

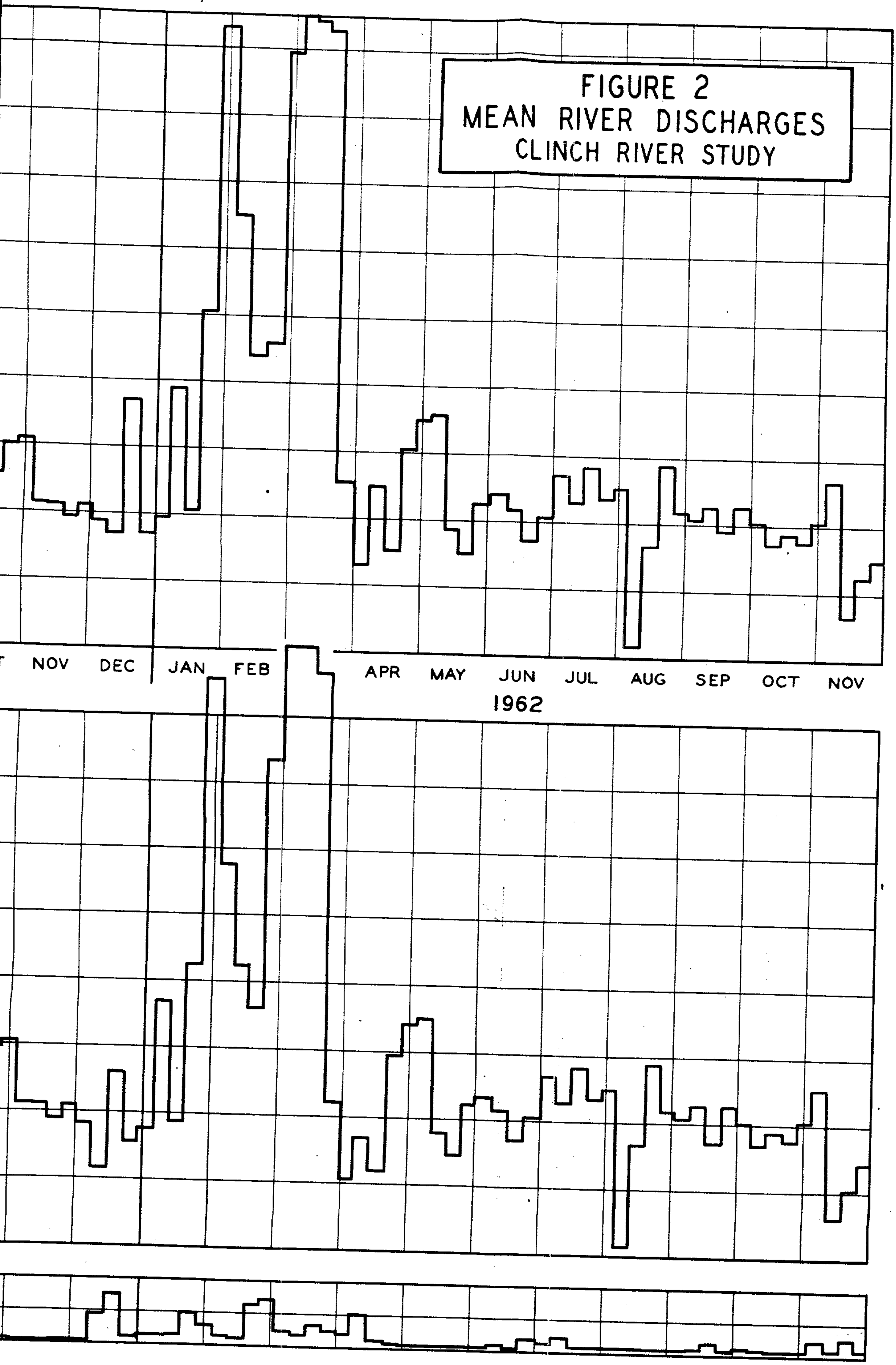
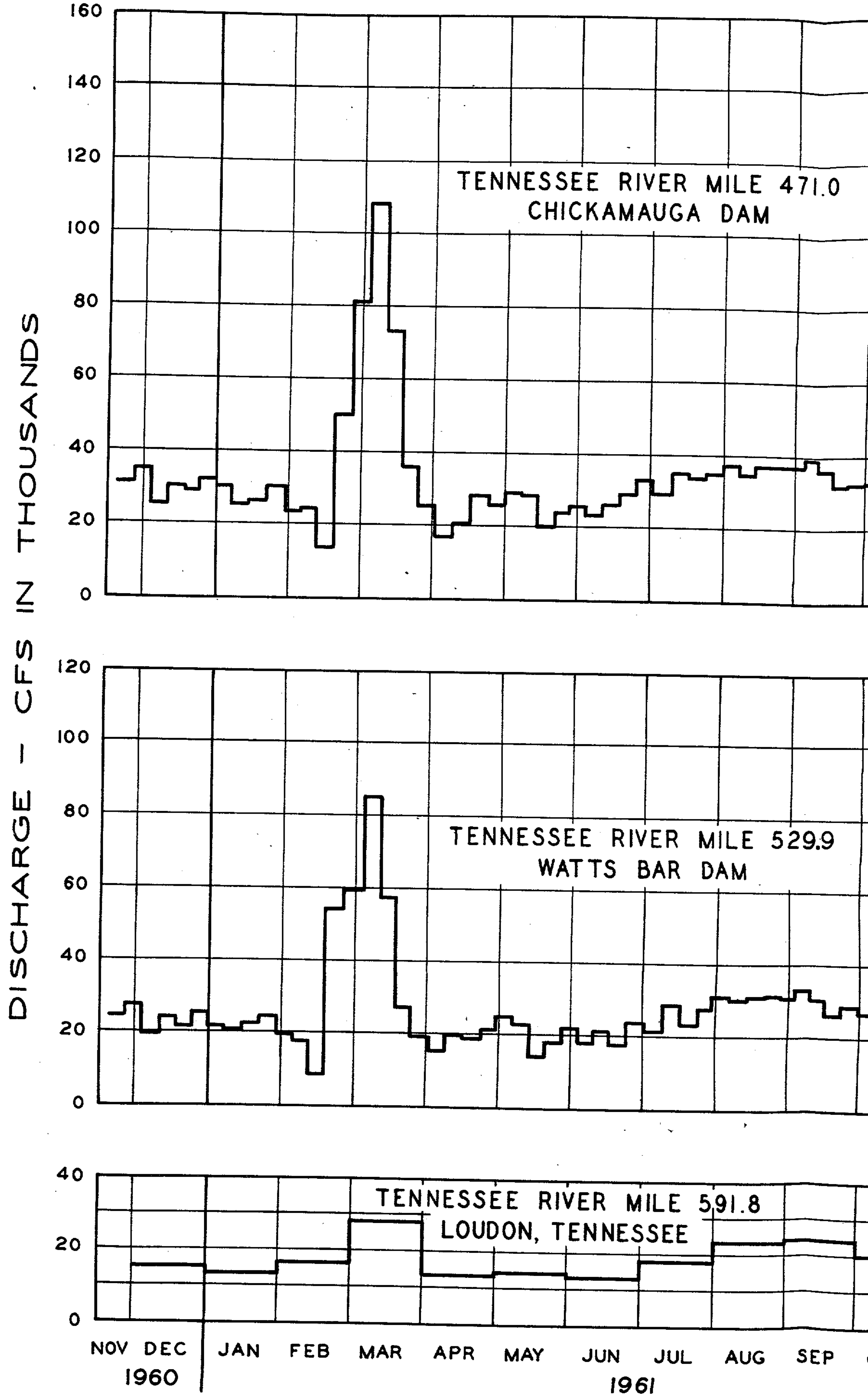


FIGURE 2
MEAN RIVER DISCHARGES
CLINCH RIVER STUDY
NOV
DEC
JAN
FEB
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
1962



DISCHARGE - CFS IN THOUSANDS
TENNESSEE RIVER MILE 471.0
CHICKAMAUGA DAM
160
140
120
100
80
60
40
20
0
TENNESSEE RIVER MILE 529.9
WATTS BAR DAM
120
100
80
60
40
20
0
TENNESSEE RIVER MILE 591.8
LOUDON, TENNESSEE
40
20
0
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
1960
1961

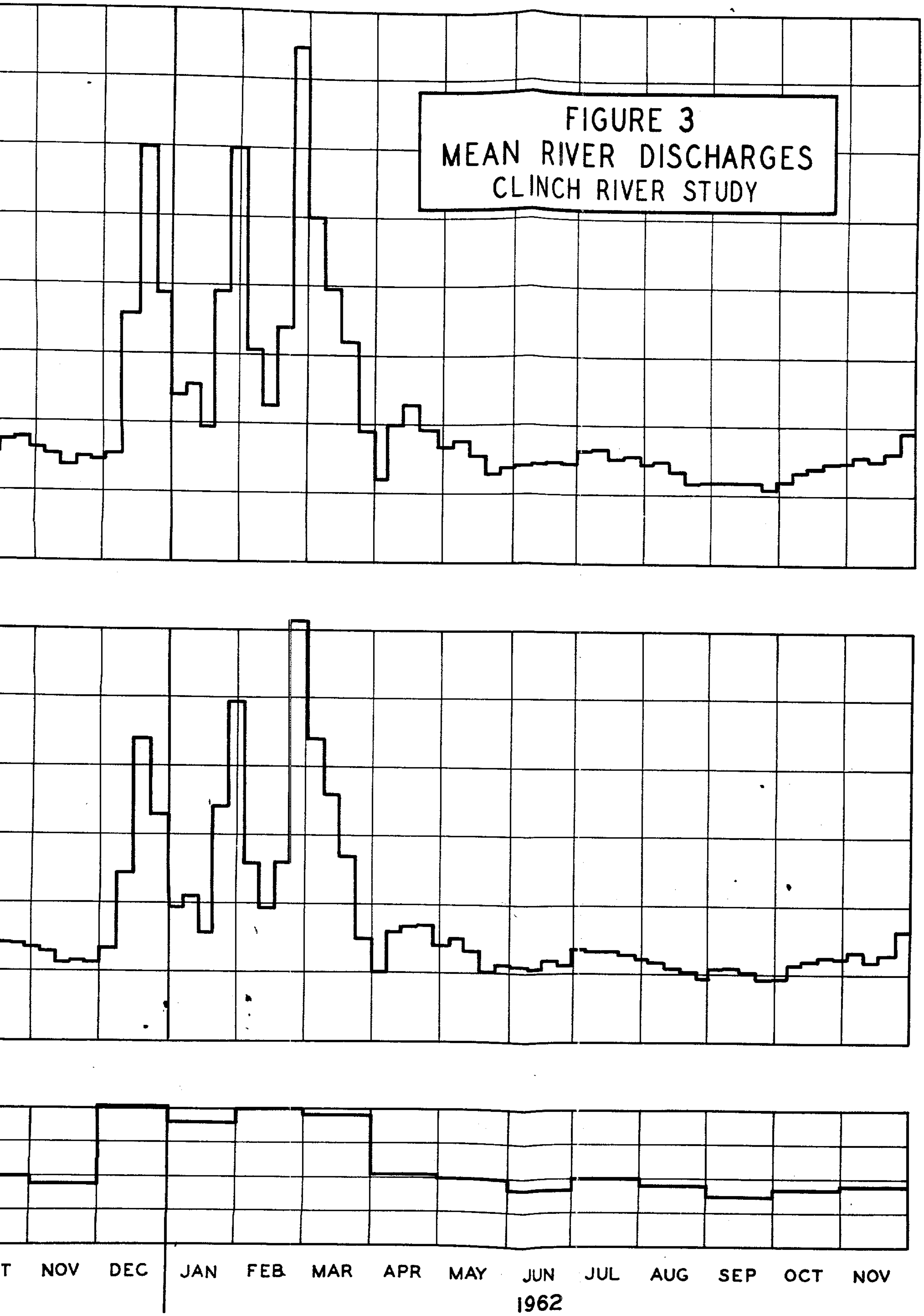


FIGURE 3
MEAN RIVER DISCHARGES
CLINCH RIVER STUDY
T NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
1962

Revision and Extension of Data Previously Reported

Progress Report No. 3, issued February 6, 1963, reported results on the four radionuclides of interest to this study from the beginning of sampling in November 1960, well into the summer of 1962. However, due primarily to a reexamination and corrections made by personnel of the U. S. Public Health Service, of the electronic computer program used to determine concentrations of cesium-137, cobalt-60, and ruthenium-106, many major changes were made in previously reported concentrations of these three radionuclides. The program in error systematically produced results that were 50 percent to 100 percent too high, for the samples of larger size (i.e., all samples except those for White Oak Creek). Correction and updating of the computer program produced the results reported here. In addition, a few changes have also been made in previously reported concentrations of strontium-90 as a result of further checking of the sample calculations. Consequently, this report includes tabulated and plotted data on all four radionuclides that supersede the data reported in Progress Report No. 3. In addition, the data on all four radionuclides at all seven stations have been extended through November 1962, i.e., to the end of the two-year sampling period. The tabulated radionuclide results are accurate to no more than two significant figures. The additional figures were tabulated for statistical reasons only.

All data reported as negative values were assumed to be zero when determining loads for the mass diagrams. This probably gives a slight positive bias to the results.

Lower Limits of Detection of Radionuclides

To assist in judging the reliability of the mass curves, information concerning the lower limits of detection of radionuclides was obtained from the U. S. Public Health Service. These data are shown in the following table. Some values below these lower limits of detection are reported in the tabulation of radionuclide concentrations and were used for calculating the cumulative loads shown in the mass diagrams.

Approximate Lower Limits of Detection*

Picocuries per liter

	Strontium-90	Cesium-137	Cobalt-60	Ruthenium-106
White Oak Creek (TS and SS)	1	11	9	45
White Oak Creek (DS)	1	67	44	190
Other Samples (TS and SS)	0.03	1	1	2
Other Samples (DS)	0.03	4	2	11

*Estimated on the basis of 2 sigma counting error associated with a blank determination (background only). The presence of any other radionuclide in a given sample would tend to raise slightly the lower limits for cesium-137, cobalt-60, and ruthenium-106.

Strontium-90, Concentrations and Total Stream Loads

Concentrations of strontium-90 found in all samples at all stations for the two-year sampling period (strontium-90 data ended November 10, 1962, at all stations except White Oak Dam and Loudon) are shown in table 1. Since some counting error is probable for every sample, the true activity level (as determined by counting) in the sample is thought to fall within the range indicated by the magnitude of the plus or minus value (95 percent confidence limits) included with each reported concentration. The plus and minus values infer the level of precision in counting rather than the accuracy of the result since some additional uncertainty arises as a consequence of the chemical separation processes involved.

Maximum concentrations found in the weekly (monthly at Loudon) composite samples (including both suspended and dissolved solids) are shown in the following tabulation:

Maximum and Mean Concentrations of Strontium-90

Station	Highest Concentration	Period of Occurrence	Flow-Weighted Mean Concentration
	pc per liter		pc per liter
Clinch R. at Oak Ridge water plant	5.0	12/4-10/60	0.71
White Oak Creek at White Oak Dam	17,450	11/13-19/60	1,349
Clinch R. at Gallaher Bridge	11.67	4/29-5/5/62	4.5*
Clinch R. at Centers Ferry	42.6	12/25-31/60	4.2
Tennessee R. at Loudon, Tenn.	2.3	January 1961	**
Tennessee R. at Watts Bar Dam	16.4	12/25-31/60	1.6
Tennessee R. at Chickamauga Dam	14.1	1/15-21/61	1.6

*Record begun January 8, 1962.

**Not applicable.

In this tabulation, the values in the last column were obtained by dividing the total cumulative stream load for the period of record by the corresponding total volume of streamflow. The mean concentration so obtained is not the same as the mean concentration over time. (In fact, it is impossible to determine the mean concentration on a time basis from the basic data.) At only the White Oak Creek station does the flow-weighted mean concentration exceed MPC values for drinking water.

Table 1

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date	Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
1960							
11/13-19	TS 1.2 ±0.03	17,450 ±450		21.6 ±0.57			
11/20-26	TS 0.92±0.2	75.6 ± 3.9		7.5 ±0.2		6.7*	1.5 ±0.08
11/27-12/3	TS 0.2 ±0.1	640 ± 6.6		14.3 ±0.4		4.8 ±0.18	0.9 ±0.02
12/4-10	TS 5.0 ±0.4	4,770 ± 20		5.0 ±0.33	1.4* for	6.7 ±0.4	4.3 ±0.14
12/11-17	TS 3.1 ±0.3	1,730 ± 15		24.1 ±0.3	December	0.7 ±0.04	5.9 ±0.57
12/18-24	TS 0.5 ±0.1	6,280 ± 22		1.5 ±0.1		2.1 ±0.1	3.6 ±0.25
12/25-31	TS 0.62±0.09	7,070 ± 74		42.6 ±1.6		16.4 ±1.30	1.4 ±0.1
1961							
1/1-7	TS 2.0 ±0.2	878 ± 8.8		13.3 ±0.32		1.98±0.009	1.7 ±0.16
1/8-14	TS 0.2 ±0.03	15,900 ± 26.2		6.3 ±0.2		4.8 ±0.3	5.6 ±0.9
1/15-21	TS 1.9 ±0.1	2,875 ± 13		4.6 ±0.1	2.3 ±0.1	12.0 ±0.6	14.1 ±0.4
1/22-28	TS 0.5 ±0.1	2,032 ± 14		3.88±0.2	for January	5.1 ±0.24	2.4 ±0.2
1/29-2/4	TS 0.3 ±0.04	6,700 ± 62		9.9 ±0.37		2.7 ±0.2	3.75±0.23
2/5-11	TS 0.8 ±0.1	3,400 ± 25		37.0 ±0.6		1.2*	2.0 ±0.25
2/12-18	TS 0.29±0.04	6,600 ± 53		30*	0.39±0.07	0.3 ±0.1	1.3 ±0.1
2/19-25	TS 0.6 ±0.1	1,350 ± 10		11.9 ±0.2	for February	0.6 ±0.1	1.7 ±0.05
2/26-3/4	TS 0.4 ±0.02	1,060 ± 8		4.1 ±0.1		2.2 ±0.2	2.8 ±0.2
3/5-11	TS 0.3 ±0.1	590 ± 7		2.9 ±0.1		1.0 ±0.04	1.5 ±0.1
3/12-18	TS 0.33±0.06	160 ± 5		1.8 ±0.1	SS Bkgd.**	0.9 ±0.1	0.8 ±0.1
3/19-25	TS 0.3 ±0.02	930 ± 80		2.5 ±0.1	DS 0.3 ±0.04	2.0 ±0.2	1.0 ±0.1
3/26-4/1	TS 0.2 ±0.02	1,000 ± 80		2.3 ±0.2	for March	0.9 ±0.1	0.3 ±0.1

*Value is estimated.

**Bkgd. indicates background.

Blank spaces indicate data not available.

TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
4/2-8	TS	0.6 ±0.1	1,020 ± 25		5.3 ±0.1		0.7 ±0.05	1.3 ±0.1
4/9-15	TS	0.3 ±0.04	953 ±128		2.7 ±0.06	SS 0.05±0.009	1.5 ±0.2	1.5 ±0.07
4/16-22	TS	0.3 ±0.02	1,208 ± 50		4.7 ±0.08	DS 0.4 ±0.04	1.2 ±0.01	1.0 ±0.07
4/23-29	SS	Bkgd.*	59.8 ± 0.09		0.1 ±0.01	for April	TS 1.3 ±0.09	TS 1.2 ±0.06
	DS	0.3 ±0.03	1,175 ±126		8.4 ±0.1			
4/30-5/6	SS	Bkgd.	110.5 ± 1.2		0.1 ±0.01		Bkgd.	Bkgd.
	DS	0.3 ±0.03	2,225 ±130		2.8 ±0.07		0.8 ±0.04	1.2 ±0.1
5/7-13	SS	Bkgd.	25.4 ± 0.8		0.1 ±0.01		0.1 ±0.01	0.1 ±0.1
	DS	0.3 ±0.03	1,462 ± 6		0.6 ±0.07		1.4 ±0.04	0.5 ±0.03
5/14-20	SS	0.1 ±0.02	18.8 ± 0.6		0.1 ±0.06	Bkgd.	Bkgd.	Bkgd.
	DS	0.3 ±0.02	1,400 ±100		4.5 ±0.1	0.3 ±0.03	1.4 ±0.03	1.6 ±0.07
5/21-27	SS	Bkgd.	12.9 ± 0.5		0.1 ±0.01	for May	Bkgd.	Bkgd.
	DS	0.3 ±0.02	1,500 ±100		9.2 ±0.1		0.69±0.04	0.8 ±0.04
5/28-6/3	SS	Bkgd.	30.0 ± 0.08		Bkgd.		Bkgd.	Bkgd.
	DS	0.5 ±0.03	2,000 ± 70		4.0 ±0.06		1.4 ±0.04	0.8 ±0.03
6/4-10	SS	0.1 ±0.01	71.8 ± 1.2		0.2 ±0.01		0.1 ±0.01	Bkgd.
	DS	0.16±0.03	1,400 ± 50		7.3 ±0.15		1.6 ±0.05	0.8 ±0.03
6/11-17	SS	0.2 ±0.02	130 ± 1.5		0.2 ±0.01	0.1 ±0.02	TS 1.80**	Bkgd.
	DS	0.4 ±0.03	1,800 ± 70		6.6 ±0.07	0.2 ±0.03		4.4 ±0.14
6/18-24	SS	1.23±0.07	80.2 ± 1.2		0.3 ±0.03	for June	Bkgd.	Bkgd.
	DS	0.3 ±0.02	1,679 ± 13		6.32±0.24		1.7 ±0.05	1.1 ±0.03

*Bkgd. indicates background.
**Value is estimated.

Blank spaces indicate data not available.
TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
6/25-7/1	SS	Bkgd.*	50.8 ± 1.0		0.3 ±0.03		Bkgd.	Bkgd.
	DS	0.2 ±0.02	1,627 ± 35.4		5.0 ±0.08		1.5**	1.5 ±0.07
7/2-8	SS	0.2 ±0.02	78.1 ± 1.1		2.5 ±0.04		Bkgd.	Bkgd.
	DS	0.2 ±0.02	2,280 ± 43		3.0 ±0.06		1.2 ±0.06	2.2 ±0.06
7/9-15	SS	0.2 ±0.02	218 ± 2		Bkgd.	0.2 ±0.05	0.4 ±0.02	Bkgd.
	DS	0.3 ±0.02	2,565 ± 40.6		1.3 ±0.04	1.96±0.1	2.0 ±0.06	0.8 ±0.04
7/16-22	SS	Bkgd.	50.3 ± 0.09		0.8 ±0.07	for July	Bkgd.	0.2 ±0.01
	DS	0.8 ±0.05	2,195 ± 53		3.0 ±0.1		1.6 ±0.04	2.0 ±0.07
7/23-29	SS	0.4 ±0.05	27.7 ± 1.8		0.21±0.06		Bkgd.	0.05**
	DS	0.36±0.04	1,920 ± 50		3.07±0.18		1.7 ±0.05	1.29±0.06
7/30-8/5	SS	0.11±0.03	23.6 ± 1.3		0.06±0.02		0.6 ±0.01	0.01±0.02
	DS	0.19±0.02	1,560 ± 36		2.1 ±0.07		0.8 ±0.05	0.49±0.05
8/6-12	SS	0.15±0.03	39.0 ± 2.7		0.13±0.12	0.02±0.01	0.04±0.02	Bkgd.
	DS	0.07±0.02	2,025 ± 41		0.6 ±0.04	0.2 ±0.02	1.2 ±0.07	1.9 ±0.07
8/13-19	SS	0.27±0.05	44.05± 1.94		0.06±0.04	for August	Bkgd.	0.02±0.02
	DS	0.15±0.14	1,651 ± 27.9		4.9 ±0.15		0.56±0.04	0.8±0.06
8/20-26	SS	0.07±0.04	64.3 ± 3.0		0.31±0.26		0.02±0.02	Bkgd.
	DS	0.13±0.11	1,275 ± 84		2.48±0.29		0.63±0.04	0.76±0.06
8/27-9/2	SS	0.08±0.06	18.8 ± 1.3		0.13±0.14		0.01±0.02	0.12±0.01
	DS	0.28±0.05	1,937 ± 35		2.89±0.14		1.1 ±0.07	0.37±0.04

*Bkgd. indicates background.
**Value is estimated.

Blank spaces indicate data not available.
SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/3-9	SS	0.14±0.04	17.8 ± 1.1		Bkgd.*		0.02±0.07	Bkgd.
	DS	0.38±0.05	1,738 ±100		1.51±0.06		0.57±0.05	0.5 ±0.05
9/10-16	SS	0.05±0.04	19.0 ± 1.2		0.22±0.01	0.04±0.02	Bkgd.	0.06±0.02
	DS	0.41±0.06	1,129 ± 89.1		2.22±0.22	0.07±0.05	1.07±0.08	0.9 ±0.06
9/17-23	SS	0.09±0.05	28.8 ± 1.58		0.17±0.15	for September	0.55±0.05	0.1 ±0.04
	DS	0.12±0.03	821.7 ± 6.93		2.0 ±0.3		0.07±0.02	0.52±0.04
9/24-30	SS	0.05±0.02	26.1 ± 1.24		0.35±0.15		0.04±0.02	0.23±0.03
	DS	0.36±0.06	1,435.5 ±147.5		1.6 ±0.17		0.32±0.03	0.05±0.05
10/1-7	SS	0.07±0.02	16.5 ± 1.2		0.23±0.03		0.08±0.02	Bkgd.
	DS	0.05±0.02	1,069.2 ±118.8		2.19±0.28		0.5 ±0.04	0.27±0.03
10/8-14	SS	0.05±0.04	10.9 ± 1.0		0.83±0.33	0.19±0.05	0.11±0.03	0.04±0.01
	DS	0.46±0.05	1,590 ±115		4.85±0.22	0.13±0.04	0.39±0.11	0.36±0.04
10/15-21	SS	0.21±0.04	17.2 ± 1.4		0.30±0.15	for October	0.31±0.02	0.03±0.02
	DS	0.46±0.70	1,810 ±195		2.41±0.32		0.5**	1.35±0.11
10/22-28	SS	0.14±0.09	9.3 ± 0.9		Bkgd.		0.15±0.06	0.05±0.02
	DS	0.4 ±0.04	1,530 ±116		1.41±0.17		1.03±0.07	0.98±0.12
10/29-11/4	SS	0.2 ±0.02	27.1 ± 1.46		0.33±0.23		0.03±0.02	Bkgd.
	DS	0.45±0.08	1,439 ±113		2.16±0.08		3.9 ±0.2	1.24±0.1

*Bkgd. indicates background.

**Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
11/5-11	SS	0.14±0.02	6.0 ± 2.34		2.0 ±0.03		TS 0.33±0.0	TS 0.94±0.12
	DS	0.4 ±0.06	1,538 ±197		6.0 ±0.5			
11/12-18	SS	0.1 ±0.03	11.4 ± 1.04		1.46±0.12	0.02±0.02	0.3 ±0.2	TS 0.7 ±0.1
	DS	0.56±0.05	1,640 ±235		6.0 ±0.44	0.33±0.07	0.4 ±0.05	
11/19-25	SS	0.09±0.04	253 ± 6.0		1.1*	for November	TS 0.5*	TS 0.9 ±0.01
	DS	0.6 ±0.02	1,560 ±145		1.9 ±0.3			
11/26-12/2	SS	Bkgd.**	20.4 ± 2.5		0.5 ±0.17		0.03±0.01	0.2 ±0.01
	DS	0.4 ±0.02	1,366 ± 89.1		2.6 ±0.09		0.4 ±0.07	0.7 ±0.06
12/3-9	SS	0.07±0.01	8.0 ± 0.73		0.2 ±0.04		0.06±0.04	0.04±0.02
	DS	0.4 ±0.07	1,564 ±102		2.8 ±0.1		0.54±0.07	1.0 ±0.01
12/10-16	SS	0.2 ±0.03	7.2 ± 0.9		0.87±0.03	0.06±0.03	0.03±0.02	0.07±0.02
	DS	0.35±0.01	782 ± 26.3		1.3 ±0.4	0.6 ±0.2	1.9 ±0.2	0.8 ±0.07
12/17-23	SS	0.16±0.04	3.89± 0.57		0.22±0.05	for December	0.08±0.02	0.04±0.03
	DS	0.4 ±0.1	454 ± 19.2		4.77±0.7		0.8 ±0.1	0.82±0.14
12/24-30	SS	0.06±0.03	Bkgd.		0.07±0.03		0.05±0.02	0.05±0.03
	DS	0.12±0.07	879 ± 19		2.29±0.32		0.67±0.05	0.06±0.02

*Value is estimated.

**Bkgd. indicates background.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
12/31-1/6	SS	0.05±0.03	6.4 ± 1.2		0.03±0.02		0.07±0.02	Bkgd.*
	DS	0.5 ±0.08	816 ± 28		1.7 ±0.36		1.4 ±0.17	0.81±0.18
1/7-13	SS	0.07±0.06	5.21± 0.7	0.2 ±0.04	0.4 ±0.03	0.13±0.04	0.08±0.03	0.35±0.02
	DS	0.7 ±0.07	636 ± 14.3	1.6 ±0.3	0.79±0.07	0.5 ±0.02	0.71±0.10	0.7 ±0.1
1/14-20	SS	0.07±0.03	5.3 ± 2.4	0.9 ±0.07	0.06±0.06	for January	Bkgd.	0.04±0.02
	DS	0.4 ±0.01	719 ± 28.2	6.20±0.8	1.52±0.07		0.95±0.14	0.70±0.12
1/21-27	SS	0.1 ±0.03	10.28± 0.96	0.22±0.04	0.03±0.01		0.29±0.03	Bkgd.
	DS	0.53±0.13	714 ± 35.3	5.0 ±0.8	4.2 ±0.4		0.57±0.13	0.59±0.10
1/28-2/3	SS	0.1 ±0.04	6.87± 0.83	0.49±0.17	TS 1.6**		0.05±0.01	0.1 ±0.03
	DS	0.53±0.04	572 ± 17	1.01±0.54			0.6 ±0.1	1.34±0.22
2/4-10	SS	0.12±0.03	13.87± 1.54	0.02±0.02	TS 1.3**	0.46±0.23	0.06±0.02	0.03±0.02
	DS	0.4 ±0.01	1,129 ± 42	1.0 ±0.2		0.7 ±0.5	0.92±0.43	0.14±0.08
2/11-17	SS	0.03±0.02	6.6 ± 1.07	0.12±0.03	0.21±0.01	for February	0.03±0.02	Bkgd.
	DS	0.2 ±0.04	1,285 ± 56.6	1.54±0.71	1.21±0.34		0.8 ±0.3	0.6 ±0.2
2/18-24	SS	0.28±0.04	20.1 ± 1.2	0.13±0.03	0.09±0.02		0.11±0.02	0.03±0.02
	DS	0.8 ±0.02	577 ± 7.28	3.7 ±0.4	2.0 ±0.53		3.0 ±0.3	2.18±0.43
2/25-3/3	SS	0.22±0.05	8.5 ± 0.94	0.15±0.11	0.14±0.06		0.05±0.02	0.25±0.03
	DS	0.28±0.27	122.9 ± 5.35	2.5 ±0.3	7.5 ±0.2		1.48±0.21	5.4 ±0.4

*Bkgd. indicates background.

**Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
3/4-10	SS	0.1 ±0.03	8.8 ± 0.9	0.08±0.03	0.2 ±0.04		Bkgd.*	0.04±0.02
	DS	0.9 ±0.2	636 ± 33.3	1.9 ±0.04	1.4 ±0.2		0.73±0.04	1.18±0.2
3/11-17	SS	0.84±0.03	TS 1,500**	0.16±0.06	0.1 ±0.05	0.05±0.02	0.05±0.03	0.03±0.01
	DS	0.6 ±0.01		1.1 ±0.1	0.85±0.12	0.37±0.04 for March	0.23±0.06	0.3 ±0.04
3/18-24	SS	0.16±0.03	18.4 ± 1.22	0.09±0.04	0.15±0.03		0.03±0.02	0.03**
	DS	0.6 ±0.07	1,101 ± 97.8	2.2 ±0.2	2.3 ±0.39		1.8 ±0.2	1.7 ±0.3
3/25-31	SS	0.04±0.02	4.28± 0.81	0.19±0.05	0.09±0.05		0.06±0.02	0.04±0.02
	DS	0.8 ±0.15	1,420 ±101	4.8 ±0.2	3.1 ±0.2		1.09±0.1	1.19±0.08
4/1-7	SS	0.08±0.03	5.08± 1.01	0.2**	0.09±0.02		0.05±0.02	0.09±0.02
	DS	0.6 ±0.1	1,600**	10.0 ±0.55	0.62±0.52		1.4 ±0.2	1.51±0.21
4/8-14	SS	0.2 ±0.05	6.85± 0.75	0.05±0.05	Bkgd.	0.05±0.04	0.05±0.02	0.02±0.01
	DS	1.05±0.25	527 ± 12	6.0 ±0.6	13.32±1.81	0.62±0.17 for April	3.36±0.3	1.21±0.15
4/15-21	SS	0.04±0.02	12.1 ± 1.7	Bkgd.	0.12±0.05		0.17±0.03	0.02**
	DS	0.4 ±0.04	1,368 ± 14	8.45±0.28	7.49±0.22		1.61±0.16	2.04±0.15
4/22-28	SS	0.05±0.02	10.4 ± 0.91	0.07±0.02	Bkgd.		0.04±0.02	0.03±0.01
	DS	1.57±0.10	2,000**	4.45±0.20	2.94±0.42		1.85±0.12	4.45±0.2
4/29-5/5	SS	0.04±0.01	18.75± 1.53	0.06±0.02	0.16±0.03		0.05±0.0[illegible]	0.04±0.03
	DS	0.87±0.08	2,700**	11.61±0.46	1.99±0.42		4.15±0.14	1.11±0.07

*Bkgd. indicates background.

**Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
5/6-12	SS	0.05±0.02	15.0 ± 1.06	0.83±0.03	0.11±0.02		0.04*	0.05*
	DS	0.51±0.09	2,852 ±178	2.17±0.37	1.85±0.36		1.34±0.07	1.07±0.14
5/13-19	SS	0.06±0.02	13.8 ± 1.4	0.09±0.02	0.09±0.02	0.05±0.02	Bkgd.**	0.06±0.02
	DS	0.54±0.11	2,700*	3.75±0.43	4.85±0.43	0.99±0.17	2.35±0.31	1.02±0.13
5/20-26	SS	0.02±0.02	25.2 ± 1.44	0.11±0.03	0.11±0.07	for May	0.05±0.02	0.29*
	DS	0.72±0.19	2,400 ±144	2.55±0.35	4.23±0.28		0.08±0.01	0.99±0.13
5/27-6/2	SS	0.06±0.02	21.8 ± 1.29	0.16±0.03	0.12±0.03		0.02±0.02	0.17*
	DS	0.62±0.16	1,900*	4.27±0.53	3.3 ±0.81		1.11±0.14	1.58±0.16
6/3-9	SS	0.07±0.03	2.85± 0.15	0.33±0.01	0.2*		0.05±0.02	0.06±0.02
	DS	0.87±0.13	1,579 ±122.5	8.5 ±0.65	4.9 ±0.53		1.23±0.16	1.26±0.25
6/10-16	SS	0.25±0.10	28.1 ± 3.23	0.22±0.04	0.21±0.07	0.04±0.02	Bkgd.	Bkgd.
	DS	0.4 ±0.08	1,258 ± 92.3	3.7 ±0.28	2.8 ±0.2	1.21±0.17	1.8 ±0.18	1.55±0.20
6/17-23	SS	0.15±0.03	23.5 ± 1.23	0.14±0.03	0.68*	for June	0.02±0.01	0.04±0.02
	DS	0.6 ±0.1	2,135 ±155.7	2.6 ±0.2	2.52±0.56		4.7 ±0.68	0.96±0.41
6/24-30	SS	Bkgd.	92.5 ± 2.48	0.24±0.04	0.99±0.07		0.11±0.03	0.05±0.03
	DS	1.2 ±0.1	1,700 ±112	2.43±0.38	3.17±0.44		1.4 ±0.2	1.5 ±0.3

*Value is estimated.

**Bkgd. indicates background.

SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/1-7	SS	0.10±0.02	126 ± 3.11	0.27±0.07			0.04±0.02	0.06±0.02
	DS	0.6 ±0.09	1,450 ±128	3.2*			1.85±0.22	1.0 ±0.1
7/8-14	SS	0.12±0.03	13.4 ± 1.1	0.19±0.03		0.05±0.02	0.15±0.03	0.06±0.03
	DS	0.58±0.10	865 ± 70.4	7.05±0.61		1.18±0.16	1.4 ±0.16	1.1 ±0.1
						for July		
7/15-21	SS	0.23±0.06	15.38± 1.03	0.05±0.02	0.03±0.02		0.07±0.06	0.5 ±0.03
	DS	0.56±0.11	1,532 ± 83	2.02±0.14	1.62±0.13		1.12±0.11	1.02±0.16
					for July 1-21			
7/22-28	SS		27.80± 1.58					
	DS		1,004 ± 58.7					
7/29-8/4	SS		16.55± 1.43					
	DS		1,972 ±219					
8/5-11	SS		3.63± 0.65					
	DS		1,008 ± 80.2					
8/12-18	SS	0.05±0.02	13.62± 1.10	0.02±0.01	0.11*	Bkgd.**	0.07±0.04	0.12±0.05
	DS	0.65±0.12	1,115 ± 81.8	2.16±0.14	1.37±0.11	0.72±0.13	2.57±0.25	1.0 ±0.12
		for July 22-August 18		for July 22-August 18	for July 22-August 18	for August		
8/19-25	SS		16.81± 0.92					
	DS		1,985 ±124					
8/26-9/1	SS		10.90± 0.83					
	DS		1,400 ±183					

*Value is estimated.

**Bkgd. indicates background.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/2-8	SS		16.95 ± 1.30					
	DS		985 ± 79					
9/9-15	SS	0.01±0.01	14 ± 0.64	0.03±0.01	0.01±0.01	0.02±0.02	0.10±0.02	0.10±0.03
	DS	0.75±0.09	1,002 ±193	2.14±0.14	1.94±0.14	0.55±0.08	1.45±0.15	1.15±0.11
9/16-22	SS	for Aug. 19-Sept. 15	22.28 ± 1.32	for August 19-Sept. 15	for August 19-Sept. 15	for September		
	DS		1,133 ±168					
9/23-29	SS		16.10 ± 1.10					
	DS		1,573 ±214					
9/30-10/6	SS		14.60 ± 0.89					
	DS		997 ±198					
10/7-13	SS	0.20±0.06	9.38 ± 0.76	0.03±0.01	0.01±0.01		0.03±0.02	0.53±0.05
	DS	0.76±0.09	1,226 ± 97.2	1.93±0.14	2.29±0.26		0.88±0.09	1.13±0.12
10/14-20	SS	for Sept. 16-Oct. 13	2.66 ± 0.79	for Sept. 16-Oct. 13	for Sept. 16-Oct. 13	0.04±0.02		
	DS		986 ±161			0.38±0.08		
10/21-27	SS		0.50 ± 0.38			for October		
	DS		1,171.2 ± 72.4					

Blank spaces indicate data not available.
SS = suspended solids; DS = dissolved solids.

Table 1 (Continued)

CONCENTRATIONS OF STRONTIUM-90, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
10/28-11/3	SS		2.86 ± 0.45					
	DS		1,326 ± 178					
11/4-10	SS	0.25 ± 0.05	1.79 ± 0.42	0.03 ± 0.01	0.04 ± 0.01		0.03 ± 0.02	0.14 ± 0.03
	DS	0.94 ± 0.13	500 ± 124	4.36 ± 0.28	2.36 ± 0.25		0.01 ± 0.01	1.11 ± 0.12
		for Oct. 14-Nov. 10		for Oct. 14-Nov. 10	for Oct. 14-Nov. 10			
11/11-17	SS		1.46 ± 0.38			0.08 ± 0.03		
	DS		848 ± 73.2			0.81 ± 0.12		
						for November		
11/18-24	SS		7.69 ± 0.75					
	DS		236 ± 26.3					
11/25-12/1	SS		8.00 ± 1.60					
	DS		1,155 ± 164.0					

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

To determine what portion of the total strontium-90 activity is associated, on the average, with the suspended solids, and what portion with the dissolved solids (meaning in solution and/or associated with very fine suspended particles not removed by the supercentrifuge), a simple average percentage was computed for each of the two portions from the determinations on all samples from each station, with results as shown in the following tabulation. Median values are also shown.

Distribution of Strontium-90 in Water Samples

Station	Percent Total Activity in Suspended Solids Mean	Suspended Solids Median	Dissolved Solids Mean	Dissolved Solids Median
Clinch River at Oak Ridge water plant	24	21	76	79
White Oak Creek at White Oak Dam	2	1	98	99
Clinch River at Gallaher Bridge	6	4	94	96
Clinch River at Centers Ferry	9	6	91	94
Tennessee River at Watts Bar Dam	9	6	91	94
Tennessee River at Chickamauga Dam	10	6	90	94

From these data it is quite apparent that from 90 to 98 percent of the strontium-90 activity is associated with the dissolved solids, or in other words, dissolved in the water itself. (The maximum size of sediment particles left in suspension by the supercentrifuge is estimated to be 0.7 microns.) The time of contact with the suspended solids in Clinch River appears to have some influence on the distribution of activity between suspended solids and dissolved solids since the percentage associated with the dissolved solids decreases from 98 percent at White Oak Dam to 94 percent at Gallaher Bridge, and to 91 percent at Centers Ferry. There is essentially no change, however, from Centers Ferry to Chickamauga Dam.

Mass Curves--Mass (cumulative) curves of strontium-90 loads at all stations except Loudon are shown in figure 4. The Loudon loads have been computed on the assumption that the concentrations found represent flow-weighted concentrations. These monthly loads are shown in figure 4 by the vertical bars extending up from the Centers Ferry load. In preparing all the mass curves in this report, the total activity in each sample was used in the computations; i.e., the total sample activity is determined as the sum of the activities in both the suspended and dissolved solids.

To permit comparison of the total cumulative loads, at successive stations, an estimate of the "normal" time of water travel from station to station was made and lagged time scales were used for plotting the loads accordingly. For example, water flowing out of the mouth of White Oak Creek would be expected to arrive at the Centers Ferry station

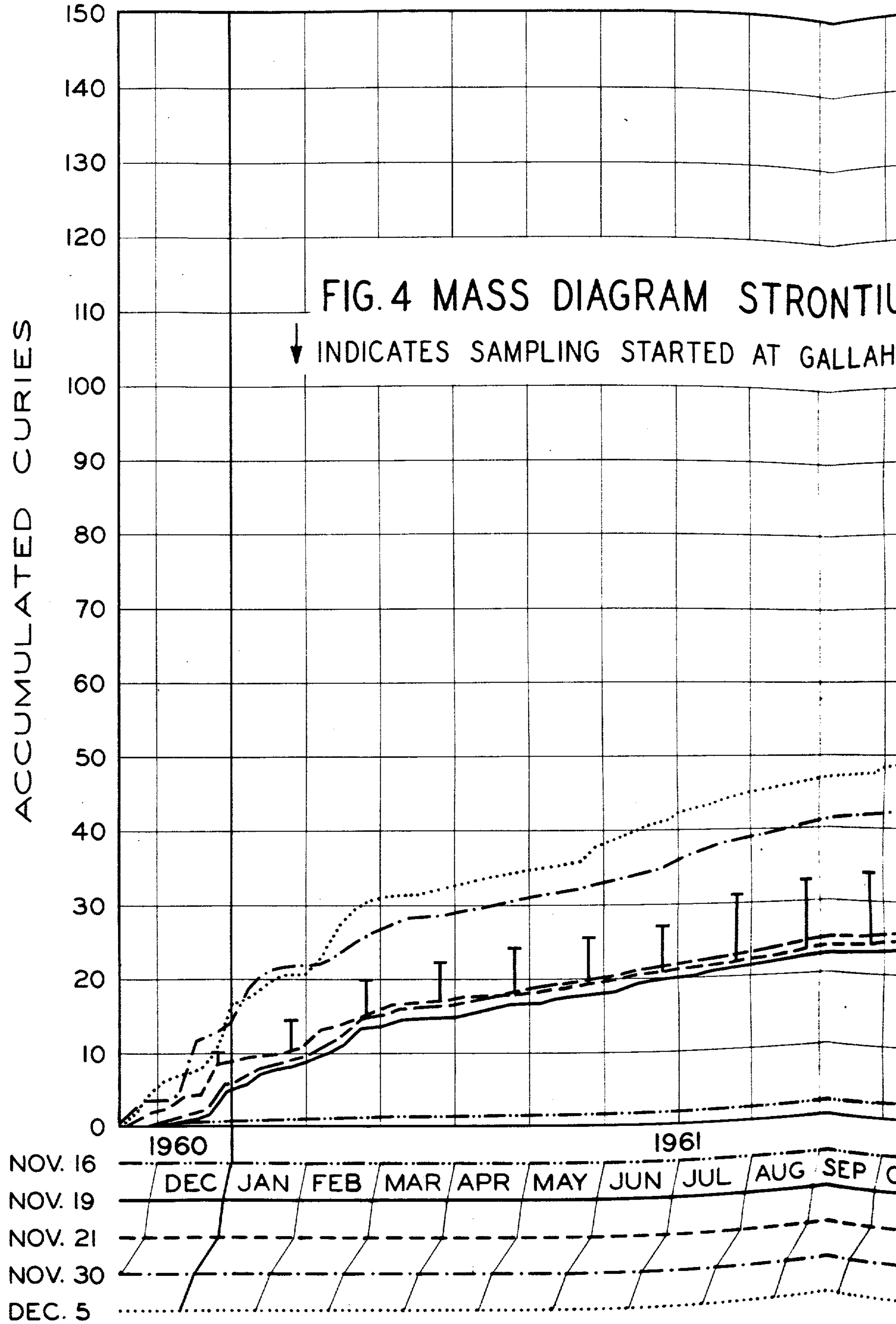
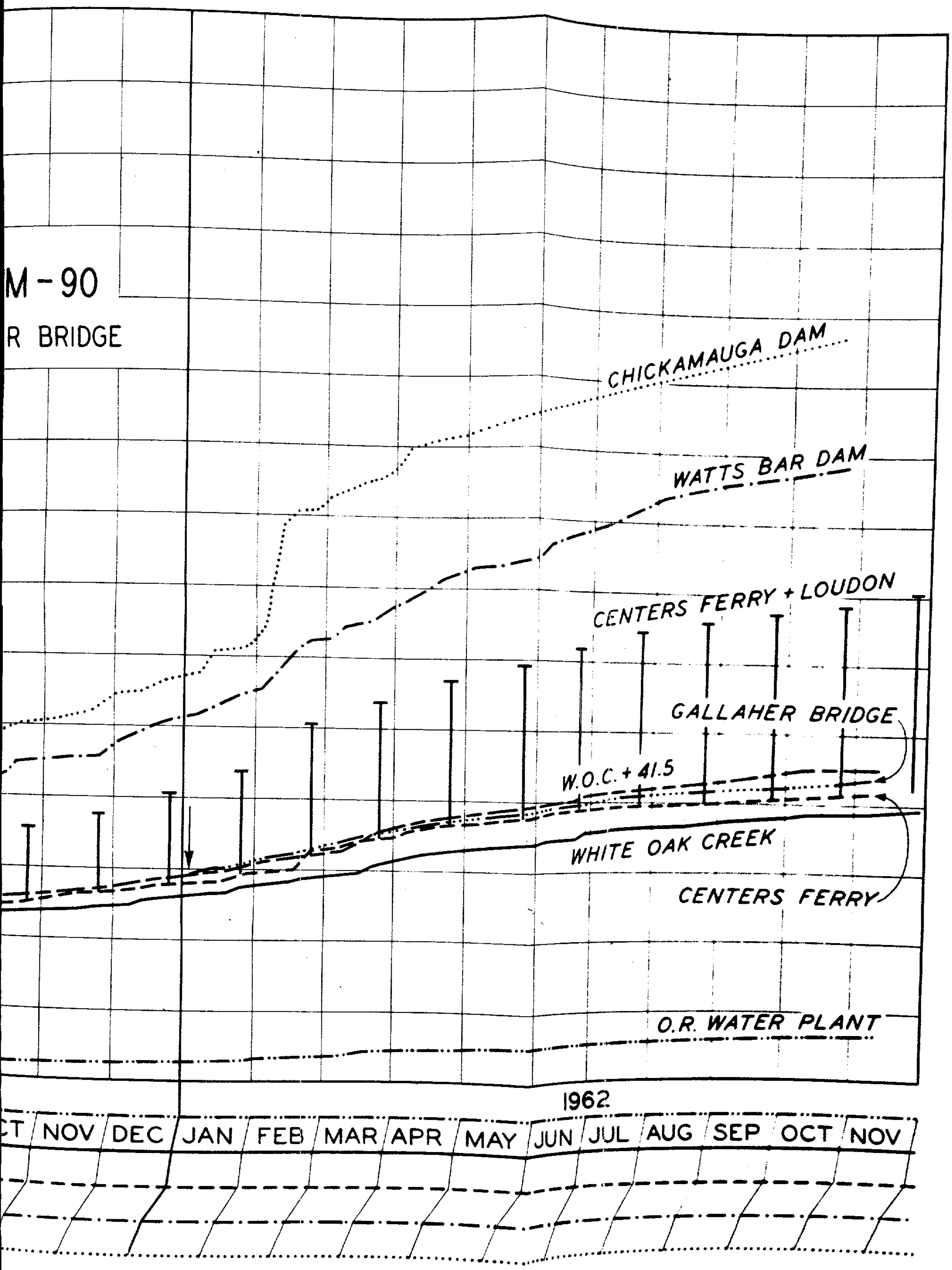


FIG. 4 MASS DIAGRAM STRONTIU
INDICATES SAMPLING STARTED AT GALLAH
ACCUMULATED CURIES
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1960
1961
NOV. 16
NOV. 19
NOV. 21
NOV. 30
DEC. 5
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP


M - 90
R BRIDGE
CHICKAMAUGA DAM
WATTS BAR DAM
CENTERS FERRY + LOUDON
GALLAHER BRIDGE
W.O.C. + 41.5
WHITE OAK CREEK
CENTERS FERRY
O.R. WATER PLANT
1962
CT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV

(Clinch River mile 5.5) two days later, and to arrive at Watts Bar Dam nine days later, and at Chickamauga Dam after five more days. Naturally, these times are not constant but vary with streamflows, pool levels, and to some extent with the season of the year. A constant time of travel has been assumed, however, as detailed above, and the plotted data seem to support, over all, the estimated times reasonably well.

The rate of discharge of strontium-90 to Clinch River during the first three months of the sampling period was approximately 4.5 curies per month but at the end of February 1961 the rate was abruptly reduced to approximately 1.2 curies per month, a rate that was maintained quite uniformly throughout the remainder of the two-year sampling period.

The strontium-90 load measured for the Clinch River at the Oak Ridge water plant is also shown in figure 4. The rate of accumulation was quite steady throughout the two-year period, at about 0.29 curies per month, or at about 91 microcuries per square mile per month.

Combining the sum of the two loads, White Oak Creek and Clinch River at Oak Ridge water plant, produces a third curve, also shown in the figure. The curve representing the sum of these two loads exceeds, at the end of sampling, the load measured at Centers Ferry by approximately 13 percent. There is also a slight loss indicated between the stations at Gallaher Bridge and Centers Ferry during the 11 months of record at Gallaher Bridge. Since about 9 percent of the total strontium-90 activity at the Centers Ferry station is associated with the suspended solids, the apparent explanation for part of this loss is sedimentation in the embayment of Clinch River.

Although the daily Loudon samples were not proportioned to streamflow, if it is assumed that they were, a sizable load presumably derived from fallout is shown as flowing down the Tennessee River from the 12,220 square miles of drainage area above this station. The accumulated load, with the above assumption, was found to be about 28 curies representing a contribution, averaged over the 24 months of record, of 96 microcuries per square mile per month.

Additional gains are indicated from the 1,550 square mile drainage area between Centers Ferry plus Loudon and Watts Bar Dam. This gain was 21 curies representing a contribution of approximately 590 microcuries per square mile per month. On the assumption that the Loudon load is not correct (and since the samples were not flow-proportioned, it undoubtedly is not), if the Centers Ferry load is subtracted from the Watts Bar load the contribution per square mile from the intervening area is determined to be 151 microcuries per square mile per month.

There is a large increase in the load at Chickamauga Dam during late February 1962, presumably from fallout following numerous bomb tests (Russian and some American) during the months of September, October, and November 1961. The total accumulated increase between Watts Bar and Chickamauga Dams in the two-year period was approximately 19 curies, representing a contribution of 227 microcuries per square mile per month.

Downstream from the Centers Ferry station, there was a measured gain in the total load from station to station. However, this cannot be interpreted to mean that all the strontium-90 originating at Oak Ridge is transported past Chattanooga, Tennessee. All that can be said on this point, with a reasonable degree of confidence, is that a large percentage of the Oak Ridge load does pass Chattanooga. That quantity of strontium-90 lost from solution and suspension during the two-year sampling period was apparently more than offset by contributions to the river system from fallout. In fact, the two-year load at Chattanooga is over two and one-half times the load passing White Oak Dam.

Periods of 1961 and 1962 in which fairly frequent nuclear bomb detonations occurred in both the United States and in the USSR, together with the resultant effects on gross beta concentrations at eight remote (remote from Oak Ridge) precipitation stations are shown in figure 5. (These data were supplied by the Applied Health Physics Section.) The stations were located at Norris, Fort Loudoun, Douglas, Cherokee, Watts Bar, Great Falls, and Dale Hollow Dams, and at Berea, Kentucky.

The abrupt increases in the strontium-90 loads during February 1962 at Loudon, Watts Bar Dam, and at Chickamauga Dam would appear to reflect relatively large volumes of runoff containing strontium-90.

Comparison with Load Measured by ORNL--To determine how strontium-90 loads at White Oak Dam, as measured in this study, compare with the same loads measured by the Oak Ridge National Laboratory, these two sets of data were plotted by months in figure 6. Reported loads for several of the individual months are greatly different but for the two years of record, the total load as determined by ORNL was only about 12 percent less than that measured in the Clinch River Study.

Cesium-137, Concentrations and Total Stream Loads

Concentrations of cesium-137 found in all samples at all stations for the two-year period of record are shown in table 2. However, because of extreme difficulty in analyzing the gamma spectrum to identify the activity due strictly to cesium-137 when there is a high concentration of ruthenium-106 present, the data reported here on cesium-137 must be considered only very approximate. Cumulative loads may be reasonably correct (due to tendency for positive and negative errors to balance out), but no great confidence can be placed in any of the cesium-137 data. In retrospect it can be said that the cesium should have been separated chemically or by other means from the samples before any radiological determinations were made.

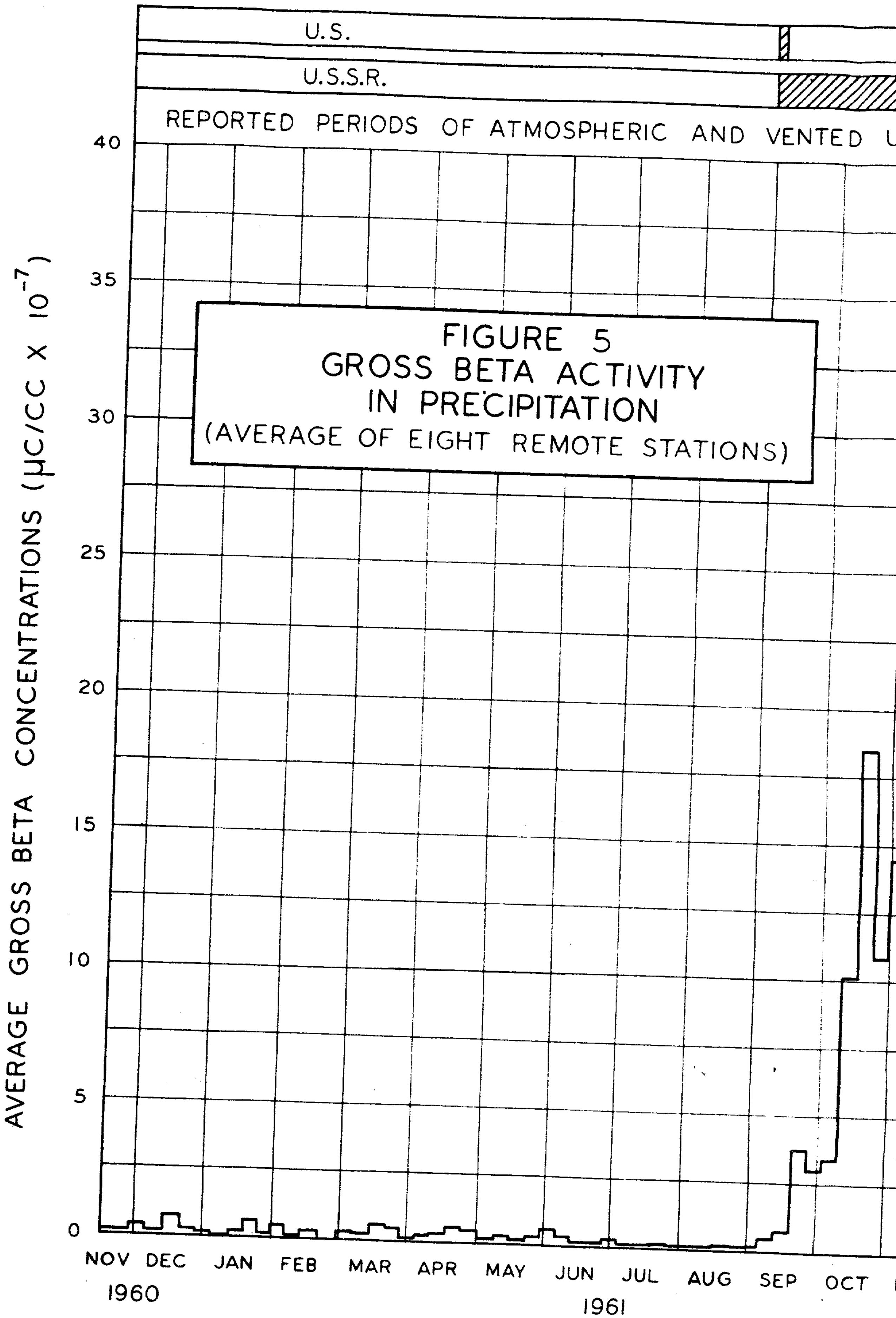
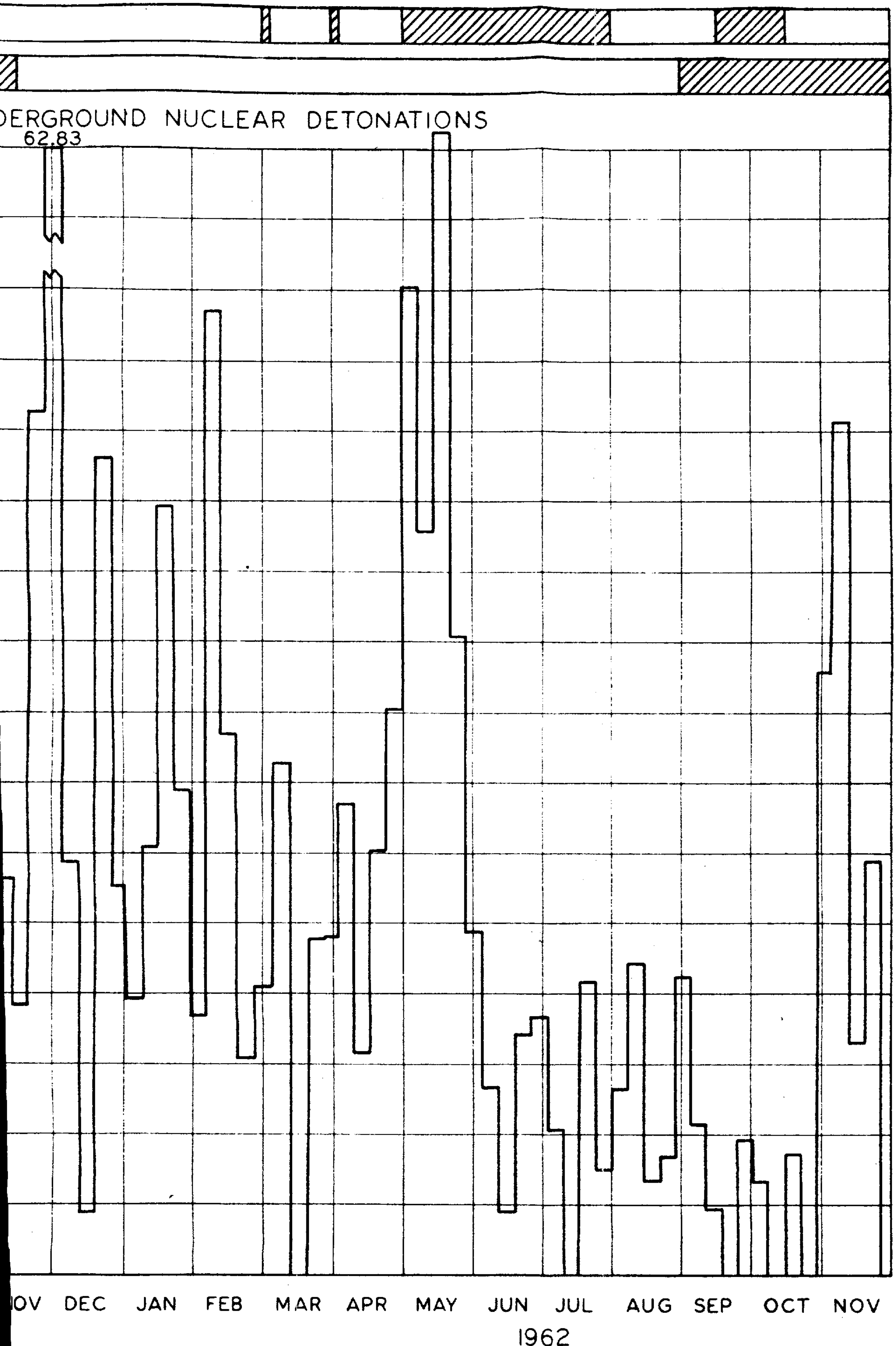
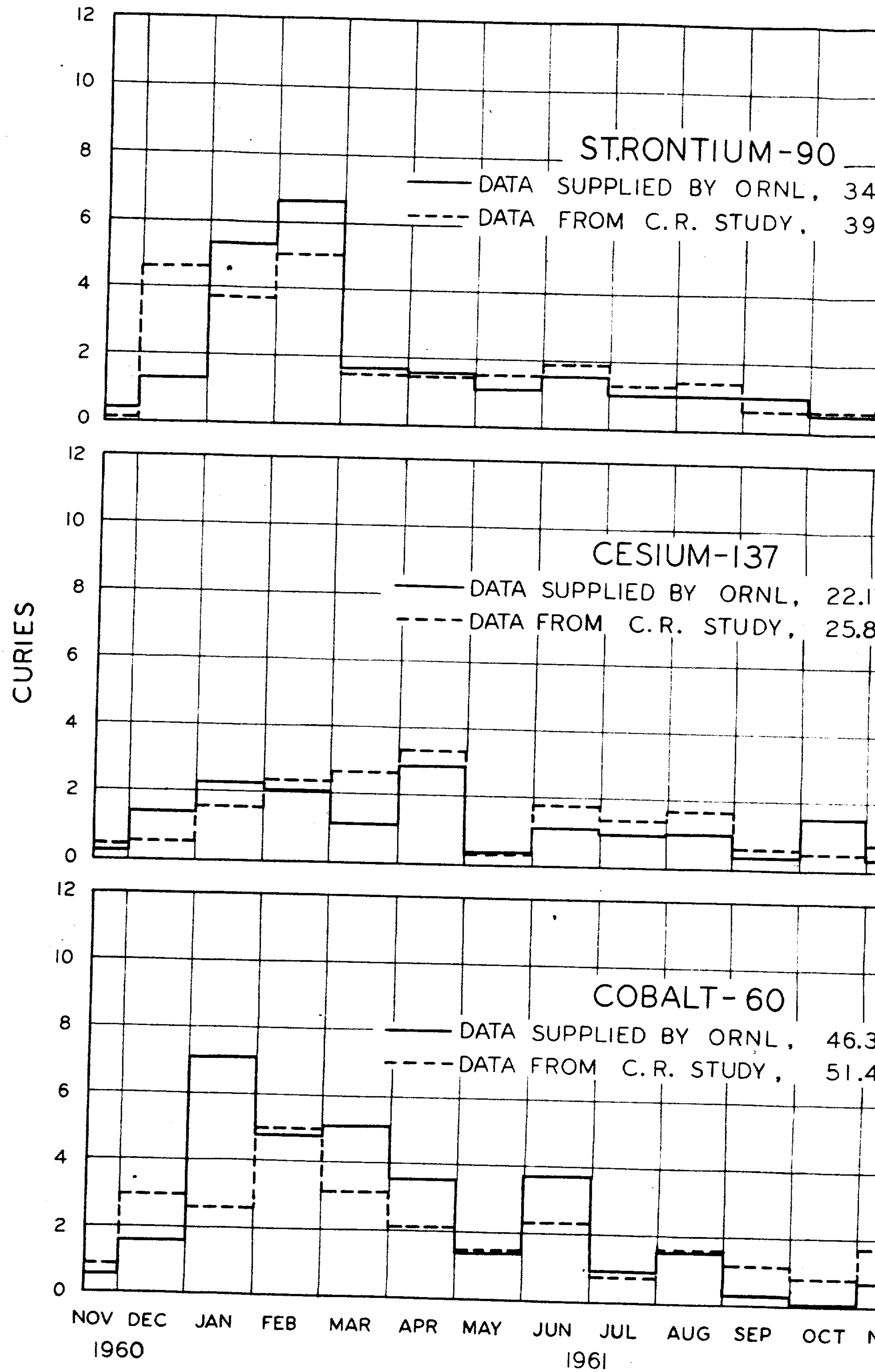


FIGURE 5
GROSS BETA ACTIVITY
IN PRECIPITATION
(AVERAGE OF EIGHT REMOTE STATIONS)


DERGROUND NUCLEAR DETONATIONS
62.83
OV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
1962


STRONTIUM-90
DATA SUPPLIED BY ORNL, 34
DATA FROM C.R. STUDY, 39
CESIUM-137
DATA SUPPLIED BY ORNL, 22.1
DATA FROM C.R. STUDY, 25.8
COBALT-60
DATA SUPPLIED BY ORNL, 46.3
DATA FROM C.R. STUDY, 51.4
CURIES
0
2
4
6
8
10
12
NOV
DEC
1960
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
1961

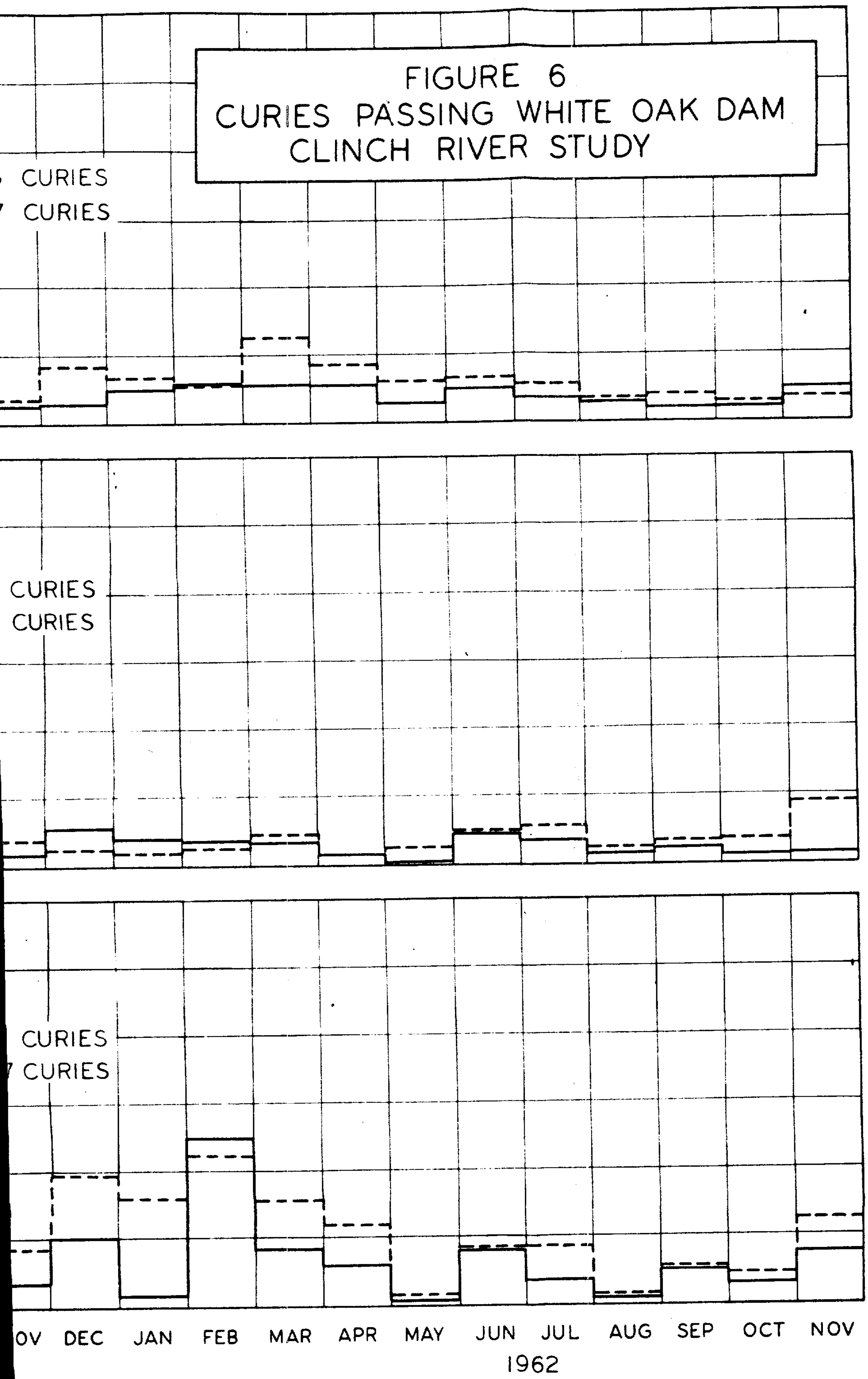


FIGURE 6
CURIES PASSING WHITE OAK DAM
CLINCH RIVER STUDY
CURIES
CURIES
CURIES
CURIES
CURIES
CURIES
OV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
1962

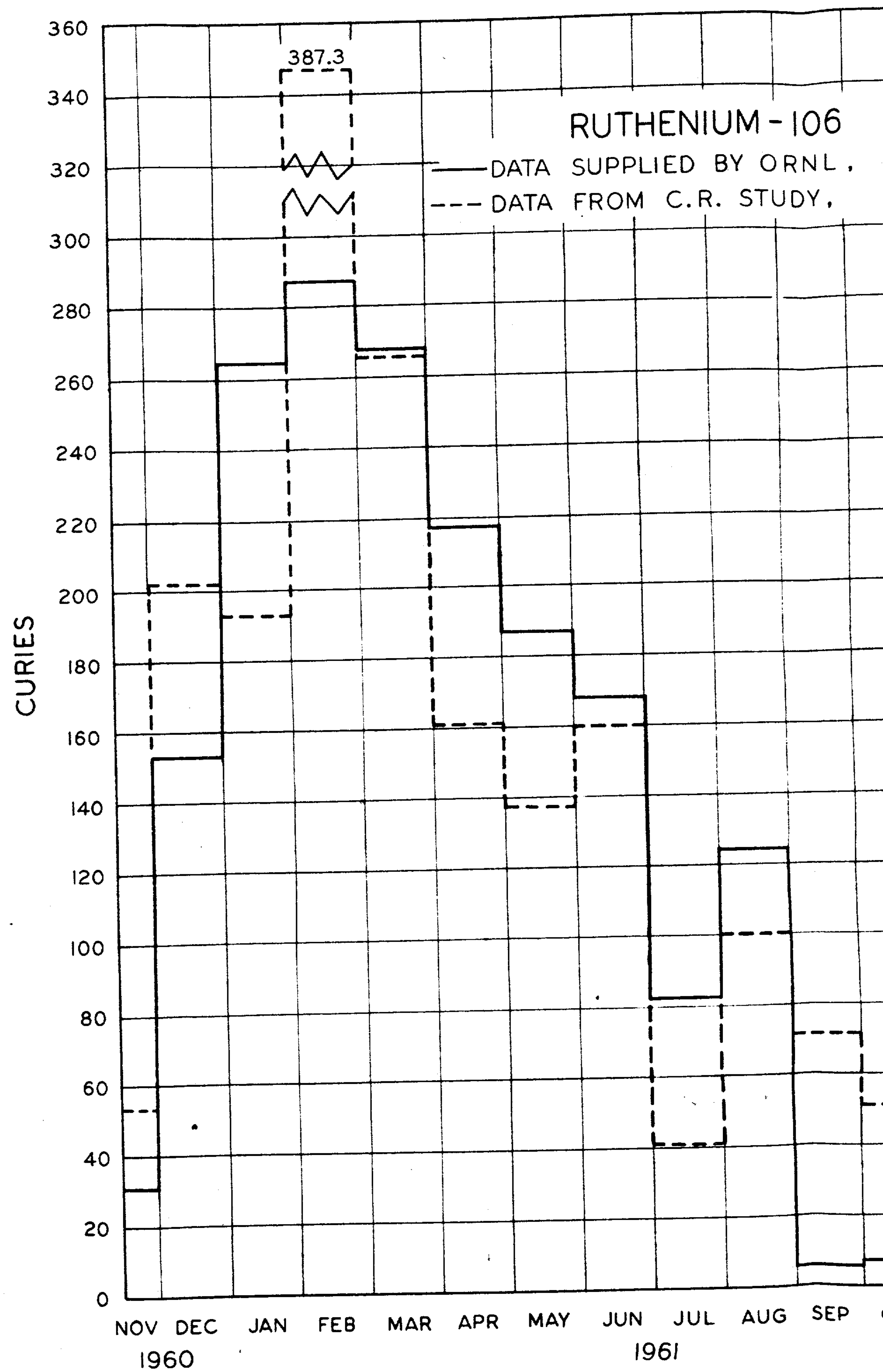

RUTHENIUM - 106
DATA SUPPLIED BY ORNL,
DATA FROM C.R. STUDY,
387.3
CURIES
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
1960
1961

FIGURE 7
CURIES PASSING WHITE OAK DAM
CLINCH RIVER STUDY

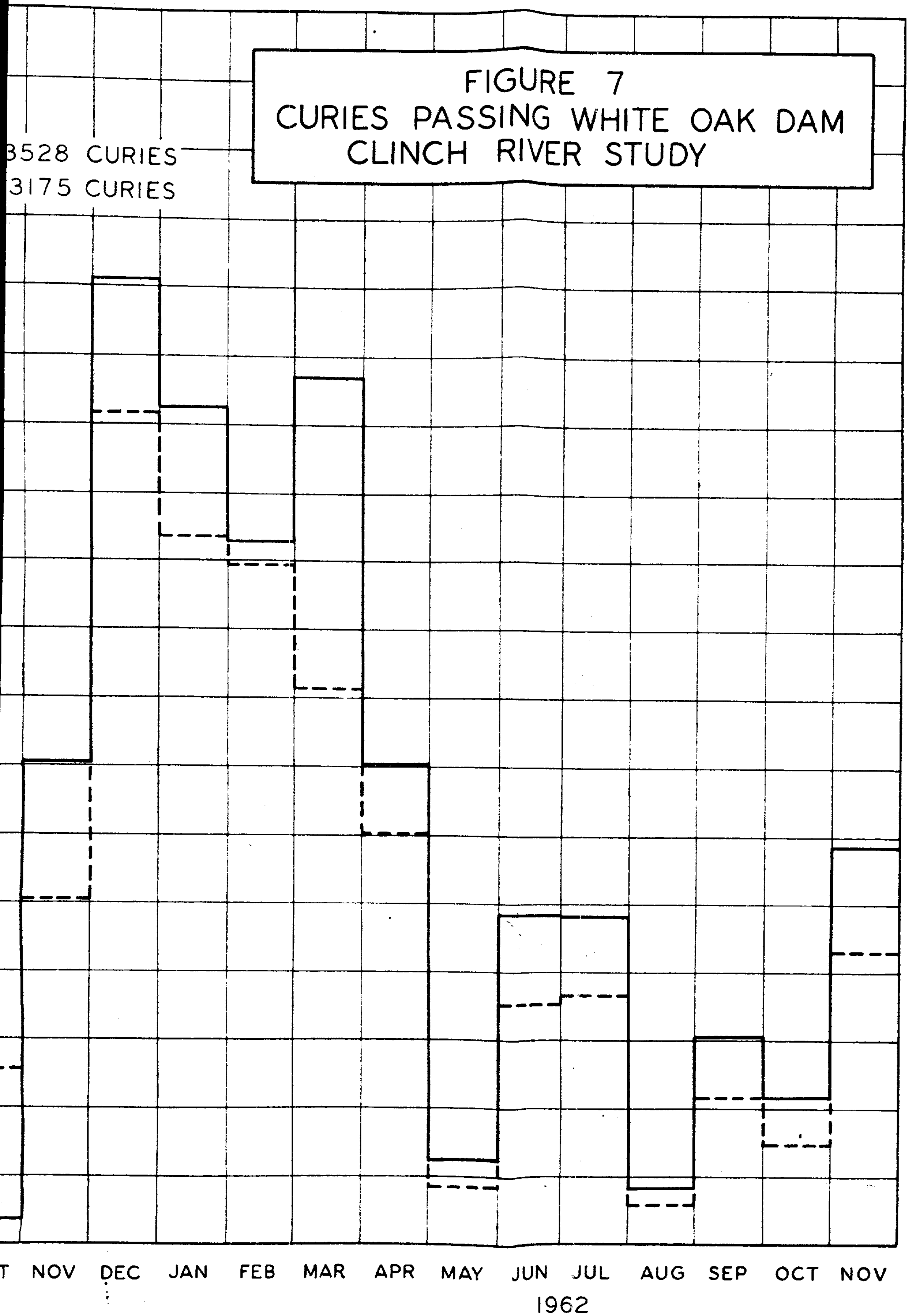


Table 2

CONCENTRATIONS OF CESIUM-137, pc per liter

Date		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
1960								
11/13-19	TS	1	978		6			
11/20-26	TS	1	-36		11			1
11/27-12/3	TS	1	4,225		6*		2	1
12/4-10	TS	2	778		4		1	0
12/11-17	TS	0	190		-7	10	1	6
12/18-24	TS	1	316		4	for December	1	2
12/25-31	TS	0	74		22		0	2
1961								
1/1-7	TS	1	696		6		0	0
1/8-14	TS	0	688		1	1	-1	0
1/15-21	TS	2	1,383		7	for January	0	0
1/22-28	TS	0	180		3		0	0
1/29-2/4	TS	3	666		1		-2	0
2/5-11	TS	1	2,978		-4		0*	0
2/12-18	TS	2	824		8	34	1	1
2/19-25	TS	5	787		3*	for February	0	0
2/26-3/4	TS	3*	366		4		2	2
3/5-11	TS	2	523		6		2	0
3/12-18	TS	1	2,082		10	SS 1	1	3
3/19-25	TS	5	2,742		6	DS 1	4	2
3/26-4/1	TS	5	1,500*		17	for March	2	4
4/2-8	TS	2	329		4		7	1
4/9-15	TS	0	4,292		1		0	0
4/16-22	TS	0	462		0	SS 0	0	0
4/23-29	SS	0*	832		5	DS 3	TS 0	TS 0
	DS	0	740		0*	for April		

*Value is estimated.
Blank spaces indicate data not available. TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
4/30-5/6	SS	0	667		3		0	1
	DS	0	43		0*		0	1
5/7-13	SS	0	377		2	0	0	0
	DS	0	0*		0*	0 for May	1	0
5/14-20	SS	0*	184		1		0	0
	DS	0	0		0		0	0
5/21-27	SS	0	341		5		0	0
	DS	0	38		1		0	0*
5/28-6/3	SS	0	632		6		0	0
	DS	0	0		0		0	0
6/4-10	SS	0	1,180*		6	0	0	0
	DS	0	0		1	0 for June	0	0
6/11-17	SS	0	1,052		7		0	0
	DS	0	-70		0		0	1
6/18-24	SS	1	747		16		0	0
	DS	0	1,310*		-3		0	0
6/25-7/1	SS	1	4,365		13		0	0
	DS	0	426		0		0	0

*Value is estimated.

Blank spaces indicate no data available.

SS = suspended solids; DS = dissolved solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/2-8	SS	6	703		1		0	0
	DS	0	87		0		0	0
7/9-15	SS	0	966		3	0	0	0
	DS	0	5,443		0	0	0	0
7/16-22	SS	0	731		4	for July	0	0
	DS	0	1,019*		0		0	0
7/23-29	SS	0	1,190		6		0	0
	DS	0	-65		1		0	0
7/30-8/5	SS	0	1,585		2		0	0
	DS	0	1,178		1		0	0
8/6-12	SS	0	2,188		8	1	0	0
	DS	0	1,492		5	6	0	0
8/13-19	SS	3	1,445		0	for August	0	0
	DS	3	-253		0		0	0
8/20-26	SS	0	1,061		4		0	0
	DS	0	-221		0		0	0
8/27-9/2	SS	0	484		1		0	0
	DS	2	1,341*		0		0	3

*Value is estimated.

Blank spaces indicate no data available.

SS = suspended solids; DS = dissolved solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/3-9	SS	0	TS 1,880*		1		0	2*
	DS	0			0		0	0
9/10-16	SS	0	TS 1,290*		2	0	0	0
	DS	0			0	-2	0	0
9/17-23	SS	0	TS 1,320*		2	for September	0	0
	DS	0			0		0	0
9/24-30	SS	0	TS 1,145*		19		0	0
	DS	0			1		0	0*
10/1-7	SS	0	636		12		0	0
	DS	0	-265		2		0	0
10/8-14	SS	0	571		49	0	0	0
	DS	2	25		6	0	0	1
10/15-21	SS	0	985		29	for October	0	0
	DS	0	315*		0		0	1
10/22-28	SS	0	1,860*		18		0	0
	DS	0	131		1		1	0
10/29-11/4	SS	0	1,156		30		0	0
	DS	0	885		4		0	0

*Value is estimated.

Blank spaces indicate no data available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
11/5-11	SS	0	106		116		TS 0	TS 0
	DS	0	1,578		8			
11/12-18	SS	0	823		94	0	0	TS 0
	DS	0	2,330		2	0*	0	
11/19-25	SS	0	159		75*	for November	TS 0*	TS 0
	DS	-2	553		1			
11/26-12/2	SS	0	349		39		0	0
	DS	0	223		1		0	0
12/3-9	SS	0	379		3		0	0
	DS	0	595		2		0	0
12/10-16	SS	0	321		5	0	0	0
	DS	0	0*		-6	0	-2	0
12/17-23	SS	0	96		5	for December	0	1
	DS	-1	0*		0*		-3	-1
12/24-30	SS	0	70		2		0	0
	DS	-1	380*		-6		18	-3

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
12/31-1/6	SS	0	88		1		0	0
	DS	-4	275*		-8		-2	-1
1/7-13	SS	0	71	1	1	0	0	0
	DS	-4	320*	-2	1	-1	-5	-3
1/14-20	SS	0	153	2	2	for January	0	0
	DS	-4	194	-2	-6		0*	0*
1/21-27	SS	0	288	6	2		0	0
	DS	0*	0*	-1	0*		-2	-3
1/28-2/3	SS	0	286	8	TS 1*		0	0
	DS	0*	0*	1			-3	1
2/4-10	SS	-1	308	4	TS 1*		0	0
	DS	0*	170*	-1			0*	-1
2/11-17	SS	0	153	5	3	0	0	0
	DS	-1	430*	-1	-2	-1	0*	0*
2/18-24	SS	-1	590	7	2	for February	0	0
	DS	-9	0*	0	3*		-2	1
2/25-3/3	SS	0	350	5	4		0	0
	DS	0	0*	-2	-2		-4	1*

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
3/4-10	SS	2	301	4	7		0	1
	DS	0	120*	0	1		3*	-4
3/11-17	SS	1	TS 630*	4	6	0	0	1*
	DS	0		-1	0	-1	5	0
3/18-24	SS	1	450	-6	5	for March	3*	0
	DS	-2	75	-4	-1		-1	-1
3/25-31	SS	0	98	5	12		1	0
	DS	-2	197	-3	-3		-1	0
4/1-7	SS	0	141	0	7		0	0
	DS	0	59	4	-2		-2	0
4/8-14	SS	2	203	TS 3*	5	1	0	0*
	DS	-1	0*		1	-1	-2	-3
4/15-21	SS	1	323	5	5	for April	1	0
	DS	0	15*	1	0		0	-2
4/22-28	SS	1	388	2	4		1	0
	DS	0	200*	-1	0		1	-1
4/29-5/5	SS	0	530*	1	2		0	0
	DS	0	288	0	0		0	1

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
5/6-12	SS	1	742	2	2		0	0
	DS	-1	202	0	0		0	-2
5/13-19	SS	0	595	4	3	0	0	0
	DS	-1	395*	-1	0	0	0	0
						for May		
5/20-26	SS	0	973	5	5		0	0
	DS	0*	225*	-2	-2		-1	0
5/27-6/2	SS	0*	1,283	8	7		0	0
	DS	0*	1	0	-1		-1	-1
6/3-9	SS	0	977	9	11		1	0
	DS	-1	425*	0	5		0	-1
6/10-16	SS	0	927	12	5	0	0	0
	DS	-3	250	1	1	-1	-1	-2
						for June		
6/17-23	SS	0	929	9	22*		0	0
	DS	-1	1,370*	0	-1		0	-1
6/24-30	SS	1	1,070	16	34		0	0
	DS	0	0*	0	1		-1	-1
7/1-7	SS	1	816	15	TS 16*		0	0
	DS	-1	410*	0*			0	-1

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/8-14	SS	1	613	18	TS 10*		0	0
	DS	0	370	-1			0	0
7/15-21	SS	0	1,194	8	0	0	0	0
	DS	0	38	1	4	1	-1	0
7/22-28	SS	0*	1,129	3	4*	for July	0*	0
	DS	0	538	0	0		0	-1
7/29-8/4	SS	1	955	1	TS 3*		0	0
	DS	0	68	0			0	0
8/5-11	SS	2	781	TS 24*	TS 49*		0	0
	DS	0	295*				0	1
8/12-18	SS	1	1,124	4	5	0	0	0
	DS	2	155*	0	0	0	0	-3
8/19-25	SS	1	1,210	3	3	for August	0	0*
	DS	1	27	0	1		1	1
8/26-9/1	SS	1	904	3	3		0	0*
	DS	-1	59	0	0		1	0*
9/2-8	SS	0	966	2	5		0	0
	DS	0	73	0	1		1	0

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/9-15	SS	1	720	6	3		0	0
	DS	0	240*	-5	1		0	0
9/16-22	SS	1	610	8	1	0	0	0
	DS	0	0*	-9	8	0 for September	1	0
9/23-29	SS	0	766	4	3		0	0
	DS	0	970*	0	5		0	0
9/30-10/6	SS	0	710	4	4		2	0
	DS	0	570*	2	0		1	0
10/7-13	SS	1	1,000	4	4		0	0
	DS	0	730	0	4		1	1
10/14-20	SS	0	493	9	5	0	0	0
	DS	0	115	2	0	1 for October	0	-1
10/21-27	SS	0*	280	12	2		0	0
	DS	1	695*	0	1		3	0
10/28-11/3	SS	0	308	11	2		0	0
	DS	1	1,820*	2	1		0	0

*Value is estimated.

SS = suspended solids; DS = dissolved solids.

Table 2 (Continued)

CONCENTRATIONS OF CESIUM-137, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
11/4-10	SS	0	282	11	1		0	0
	DS	-1	884	6	1		2	3
11/11-17	SS	1	88	13	3	0	0	2*
	DS	0	2,660*	1	4	0	1*	0
						for November		
11/18-24	SS	0*	410	9	4		1	0
	DS	-3	656	12	0*		-1	0
11/25-12/1	SS	0	359	8	1			0
	DS	0		2	3			0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Maximum concentrations found in the weekly (monthly at Loudon) composite samples (including both suspended and dissolved solids) are shown in the following tabulation:

Station	Sample Showing Highest Concentration Cesium-137	
	Concentration pc per liter	Period of Occurrence
Clinch R. at Oak Ridge water plant	6	Jul. 2-8, 1961, and Aug. 13-19, 1961
White Oak Creek at White Oak Dam	6,409	Jul. 9-15, 1961
Clinch R. at Gallaher Bridge	21	Nov. 18-24, 1962
Clinch R. at Centers Ferry	35*	Jun. 24-30, 1962
Tennessee R. at Loudon, Tenn.	34	Feb. 5-11, 1961
Tennessee R. at Watts Bar Dam	18	Dec. 24-30, 1961
Tennessee R. at Chickamauga Dam	6	Dec. 11-17, 1960

*Omitting high values during period September 10 through December 2, 1961, when sampling equipment was not functioning properly.

Since even the maximum concentrations at all stations are far below MPC values for drinking water used by the general population, mean concentrations at the various stations were not computed.

To determine what portion of the total cesium-137 activity is associated, on the average, with the suspended solids, and what portion with the dissolved solids (including, of course, those very fine suspended solids not removed by the supercentrifuge), a simple average percentage was computed for each of the two portions from the determinations made on all samples from each station, with results as shown in the following tabulation. Median concentrations are also indicated.

Distribution of Cesium-137 in Water Samples

Station	Percent Total Activity in			
	Suspended Solids		Dissolved Solids	
	Mean	Median	Mean	Median
Clinch R. at Oak Ridge water plant	82	100	18	0
White Oak Creek at White Oak Dam	69	79	31	21
Clinch River at Gallaher Bridge	92	100	8	0
Clinch River at Centers Ferry	86	100	14	0
Tennessee River at Watts Bar Dam	30	0	70	100
Tennessee River at Chickamauga Dam	19	0	81	100

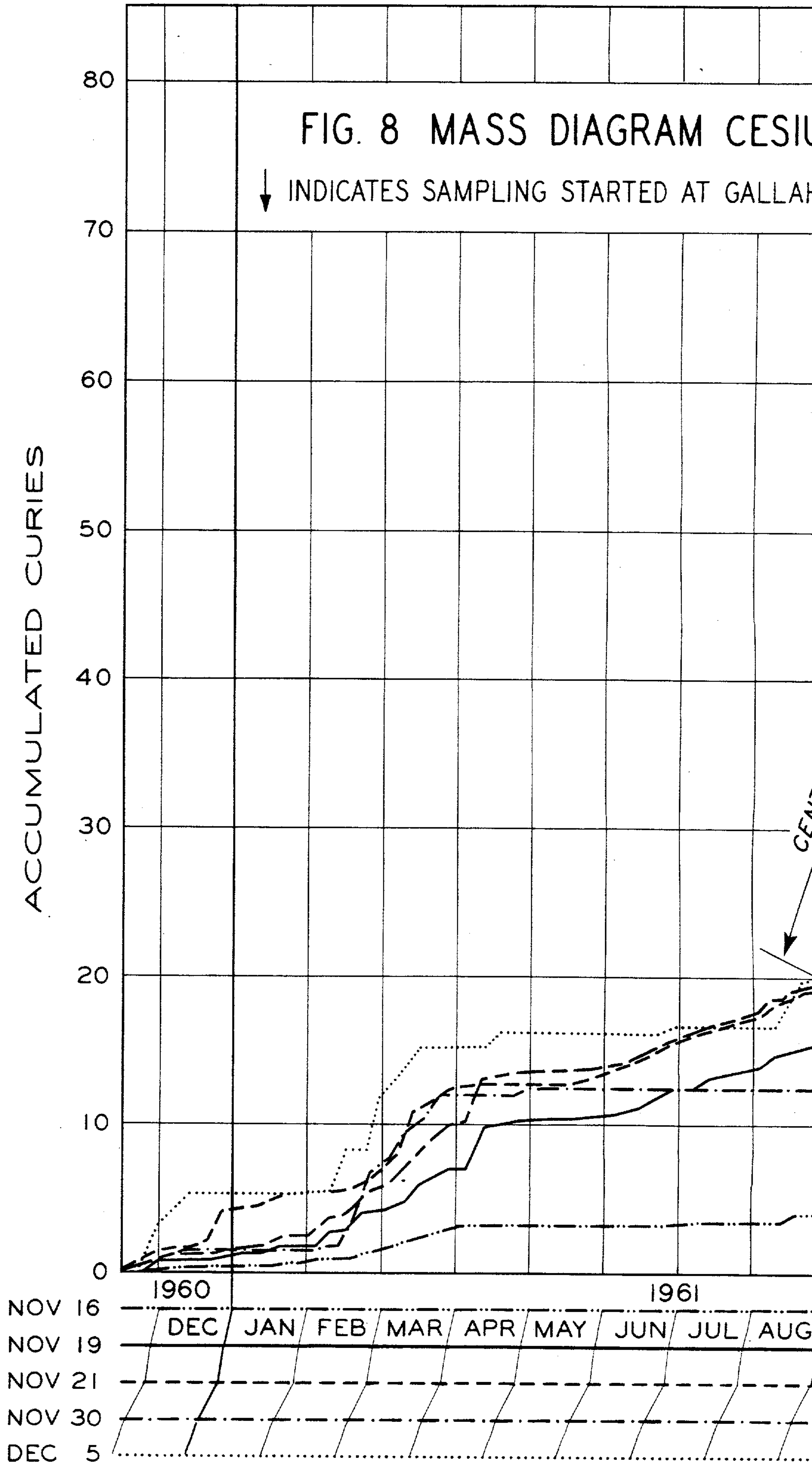
In marked contrast with strontium-90, the great bulk (69 to 92 percent) of the cesium-137 load is associated with the suspended solids in the water samples collected from White Oak Creek and from Clinch River. The Tennessee River samples, however, show 70 to 81 percent of the load to be in solution and/or associated with the very fine solids not removed by the supercentrifuge. This indicates that practically all the Clinch River sediment has settled by the time the Watts Bar Dam and Chickamauga Dam stations are reached and that only the very fine particulate matter and its contained activity remains.

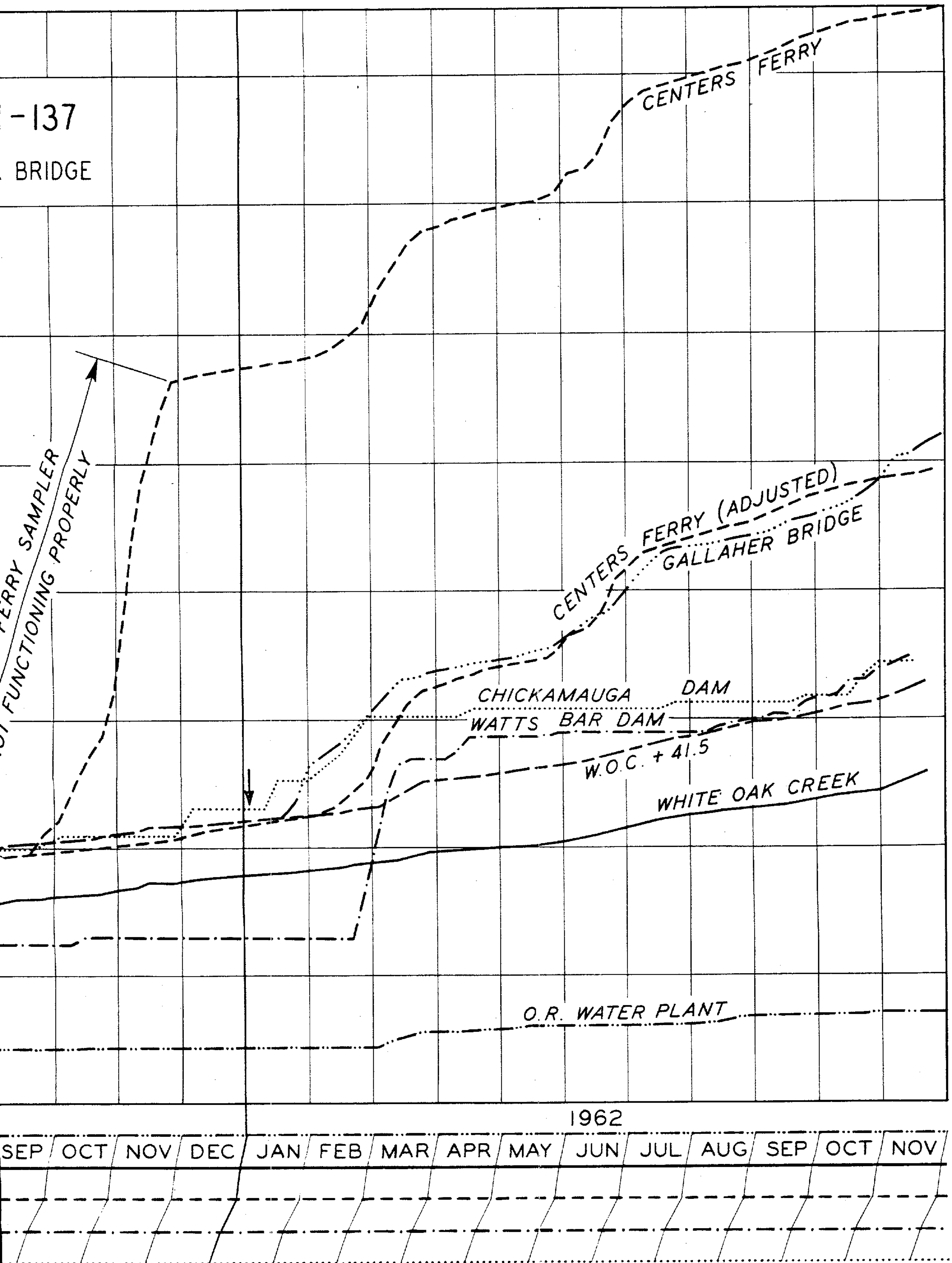
Mass Curves--Mass curves of cesium-137 loads at all stations except Loudon, are shown in figure 8. In spite of a basic lack of accuracy in all cesium-137 determinations, the agreement shown in the discussion under "Comparison with Load Measured by ORNL," page 40, indicates the mass curve for White Oak Creek probably is reasonably accurate. The rate of discharge of cesium-137 to Clinch River was quite variable for the period November 1960 to April 1961, but thereafter, through November 1962, the rate of discharge was reasonably steady at about 0.8 curie per month.

The outstanding feature of all these curves that immediately catches the eye is the extremely great load shown for Centers Ferry in the fall of 1961. Due to a malfunctioning of the sampling equipment here during this period, as explained in detail in Progress Report No. 3, the reported load is undoubtedly incorrect. If the curve value for December 1, 1961, is adjusted to about 21 curies (the value obtained by extending the curve established prior to about October 1), and the load thereafter accumulated from this value, the entire mass curve for this station appears more reasonable, and is very similar to that for Gallaher Bridge.

Although there is considerable question about the accuracy of all cesium-137 determinations, still there is an indicated increase in the cesium-137 loads during 1962 between White Oak Creek and Gallaher Bridge that is quite substantial. Such an increase might be attributed to lack of accuracy were it not for the fact that when the Centers Ferry load is plotted in the lower position as discussed above, the Gallaher Bridge and Centers Ferry loads check each other amazingly well. This increase cannot logically be attributed to scouring of silt from the riverbed in the reach between White Oak Creek and Centers Ferry since the load seems to have increased more or less continuously throughout the year, and not just during the high river flows of January, February, and March 1962. Although limited accuracy in analysis of the cesium-137 samples casts serious doubts into the situation, and although a careful field investigation of this situation has previously been made by P. H. Carrigan and R. J. Pickering, still the indication of a sizable increase in the Clinch River load of this radionuclide at some point(s) below the mouth of White Oak Creek is sufficiently definite to warrant a "second look" by personnel familiar with the possibilities of seepage from disposal pits, and with all other possible sources of this radionuclide.

FIG. 8 MASS DIAGRAM CESIU




-137
BRIDGE
CENTERS FERRY
FERRY SAMPLER
NOT FUNCTIONING PROPERLY
CENTERS FERRY (ADJUSTED)
GALLAHER BRIDGE
CHICKAMAUGA DAM
WATTS BAR DAM
W.O.C. + 41.5
WHITE OAK CREEK
O.R. WATER PLANT
1962
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV

Because of the very limited accuracy of analysis, particularly in the dilute samples collected from the Tennessee River, no detailed discussion of the mass curves for Watts Bar and Chickamauga Dams is warranted.

Comparison with Load Measured by ORNL--The data for cesium-137 plotted in figure 6 indicate reasonable agreement during most months of record between the loads as determined by the Oak Ridge National Laboratory and as determined in the Clinch River Study. The total load for the two-year period as determined by ORNL (22.17 curies) was about 14 percent less than that determined in the Clinch River Study (25.83 curies).

Cobalt-60, Concentrations and Total Stream Loads

Concentrations of cobalt-60 found in all samples at all stations for the two-year period of record are shown in table 3.

Maximum concentrations found in the weekly (monthly at Loudon) composite samples (including activity in both suspended and dissolved solids) are shown below:

Station	Sample Showing Highest Concentration Cobalt-60	
	Concentration (pc per liter)	Period of Occurrence
Clinch River at Oak Ridge water plant	5	Jul. 22-28, 1962
White Oak Creek at White Oak Dam	5,095	Nov. 12-18, 1961
Clinch River at Gallaher Bridge	18	Nov. 18-24, 1962
Clinch River at Centers Ferry	52	Jun. 11-17, 1961
Tennessee River at Loudon, Tenn.	1	*
Tennessee River at Watts Bar Dam	3	**
Tennessee River at Chickamauga Dam	3	Feb. 18-24, 1962, Jun. 17-23, 1962, and Aug. 12-18, 1962

*This value occurred in several samples throughout the sampling period.

**This value occured five times, March to October 1962, inclusive.

Table 3

CONCENTRATIONS OF COBALT-60, pc per liter

Date	Clinch River at Oak Ridge Water Plant		White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at		
						Loudon, Tenn.	Watts Bar Dam	Chickamauga Dam
1960								
11/13-19	TS	0	2,302		4			
11/20-26	TS	0	4,679		8		1*	0
11/27-12/3	TS	0	3,734		8		1	0
12/4-10	TS	2	2,521		3		1	1
12/11-17	TS	0	3,156		6	0	1	0
12/18-24	TS	0	3,147		12	for December	1	0
12/25-31	TS	1	3,391		12		1	0
1961								
1/1-7	TS	0	2,022		19		1	1
1/8-14	TS	0	2,246		2		1	1
1/15-21	TS	0	3,656		3	0	2	2
1/22-28	TS	0	2,533		3	for January	1	2
1/29-2/4	TS	0	3,611		2		1	2
2/5-11	TS	0	3,817		34		1*	1
2/12-18	TS	0	2,765		28	1	0	1
2/19-25	TS	0	1,784		5*	for February	2	1
2/26-3/4	TS	0*	1,418		4		1	1
3/5-11	TS	0	1,046		2		0	0
3/12-18	TS	0	1,526		4	SS 0	0	0
3/19-25	TS	0	1,861		2	DS 0	0	0
3/26-4/1	TS	0	1,657		3	for March	0	0
4/2-8	TS	0	1,612		13		0	0
4/9-15	TS	0	1,566		4	SS 0	0	0
4/16-22	TS	0	1,521		10	DS 0	1	0
						for April		

*Value is estimated.

Blank spaces indicate data not available. TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
4/23-29	SS	0*	157		1			
	DS	0	852		1*		TS 1	TS 0
4/30-5/6	SS	0	254		0		0	0
	DS	0	102		1		0	0
5/7-13	SS	0	182		0	0	0	0
	DS	0	1,578		7	0	1	0
						for May		
5/14-20	SS	0*	9		0		0	0
	DS	0	1,921		4		0	1
5/21-27	SS	0	69		2		0	0
	DS	0	1,303		8		0	0*
5/28-6/3	SS	0	147		1		0	0
	DS	0	928		2		1	0
6/4-10	SS	0	940*		1	0	0	0
	DS	0	1,893		2	0	0	0
						for June		
6/11-17	SS	0	302		3		0	0
	DS	0	2,037		49		0	1
6/18-24	SS	0	240		3		0	0
	DS	0	1,831		15		0	0
6/25-7/1	SS	0	201		2		0	0
	DS	0	1,051		6		0	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/2-8	SS	0	125		1		0	0
	DS	0	791		0		0	1
7/9-15	SS	0	210		0	0	0	0
	DS	0	2,104		1	0	1	1
7/16-22	SS	0	1,191		4	for July	0	0
	DS	0	0*		4		1	1
7/23-29	SS	0	151		1		0	0
	DS	0	541		2		0	0
7/30-8/5	SS	0	1,018		0		0	0
	DS	0	1,163		0		0	0
8/6-12	SS	0	344		0		0	0
	DS	0	1,767		0		0	0
8/13-19	SS	0	407		0	0	0	0
	DS	0	1,192		0	0	0	0
8/20-26	SS	0	248		1	for August	0	0
	DS	0	1,119		4		0	0
8/27-9/2	SS	0	111		0		0	0
	DS	0	2,625*		1		0	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/3-9	SS	0	TS 3,155*		0		0	0*
	DS	0			0		0	0
9/10-16	SS	0	TS 2,490*		0	0	0	0
	DS	0			0	0 for September	0	1
9/17-23	SS	0	TS 2,644*		0		0	0
	DS	0			0		0	0
9/24-30	SS	0	TS 2,061*		2		0	0
	DS	0			0		0	0*
10/1-7	SS	0	112		1		0	0
	DS	0	1,044		1		0	0
10/8-14	SS	0	115		5	0	0	0
	DS	0	747		2	0 for October	0	0
10/15-21	SS	0	123		4		0	0
	DS	0	1,175*		0		0	0
10/22-28	SS	0	3,175*		2		0	0
	DS	0	417		1		0	0
10/29-11/4	SS	0	215		4		0	1
	DS	0	3,694		4		0	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
11/5-11	SS	0	68		16		TS 0	TS 0
	DS	0	3,097		6			
11/12-18	SS	0	286		12	0	0	TS 0
	DS	0	4,809		3	0*	1	
						for November		
11/19-25	SS	0	103		5*		TS 0*	TS 0
	DS	0	3,293		7			
11/26-12/2	SS	0	139		7		0	0
	DS	0	2,230		2		1	1
12/3-9	SS	0	102		0		0	0
	DS	0	3,734		9		1	0
12/10-16	SS	0	130		1	0	0	0
	DS	0	2,208		14	0	2	0
						for December		
12/17-23	SS	0	53		1		0	0
	DS	0	730		16		0	1
12/24-30	SS	0	45		1		0	0
	DS	0	1,771		6		1	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
12/31-1/6	SS	0	74		0		0	0
	DS	0	1,699		5		0	0
1/7-13	SS	0	87	0	0		0	0
	DS	0	1,875*	1	6		1	0
1/14-20	SS	0	66	1	0	0	0	0
	DS	1	1,659	9	1	0 for January	0	1
1/21-27	SS	0	175	1	1		0	0
	DS	0	1,602	8	20		1	0
1/28-2/3	SS	0	134	1	TS 10*		0	0
	DS	0	773	1			0	0
2/4-10	SS	0	1,584	4	TS 12*		0	0
	DS	0	3,499	5			-1	1
2/11-17	SS	0	371	2	2	0	0	0
	DS	1	2,608	2	5	1 for February	1*	2*
2/18-24	SS	0	326	2	1		0	0
	DS	1	1,129	10	4		2	3
2/25-3/3	SS	0	242	1	1		0	0
	DS	0	844	6	3		3	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
3/4-10	SS	0	173	1	1		0	0
	DS	1	1,216	3	1		0	1
3/11-17	SS	0	TS 1,675*	0	1	0	0	0*
	DS	1		1	0	1	1	0
3/18-24	SS	0	248	-2	1	for March	0*	0
	DS	0	796	0	3		2	2
3/25-31	SS	0	60	2	1		0	0
	DS	1	1,468	6	1		1	1
4/1-7	SS	0	94	0	1		0	0
	DS	1	1,483	13	1		3	2
4/8-14	SS	0	129	3	2	0	0	0*
	DS	0	1,384	3*	13	1	1	1
4/15-21	SS	0	122	2	1	for April	1	0
	DS	1	1,108	7	5		1	1
4/22-28	SS	0	90	1	1		1	0
	DS	3	1,026	1	1		2	1
4/29-5/5	SS	0	0*	0	1		0	0
	DS	2	1,420	1	0		3	1

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
5/6-12	SS	0	150	1	0		0	0
	DS	0	692	1	1		2	0
5/13-19	SS	0	74	1	0	0	0	0
	DS	1	198	1	2	1	0	0
5/20-26	SS	0	136	1	1	for May	0	0
	DS	0*	40	2	1		0	1
5/27-6/2	SS	0*	187	0	1		0	0
	DS	0*	423	1	0		1	0
6/3-9	SS	0	436	2	3		0	0
	DS	0	1,931	4	7		0	1
6/10-16	SS	0	584	3	2	0	0	0
	DS	0	2,540	6	5	0	0	0
6/17-23	SS	0	258	2	8*	for June	0	0
	DS	0	910	2	3		2	3
6/24-30	SS	0	575	4	6		0	0
	DS	1	1,392	4	6		2	0

*Value is estimated.

SS = suspended solids; DS = dissolved solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/1-7	SS	0	534	4	TS 8*		0	0
	DS	1	1,359	4*			1	0
7/8-14	SS	0	392	4	TS 2*	0	0	0
	DS	1	1,822	5		1	3	1
7/15-21	SS	0	173	2	0	for July	0	0
	DS	1	56	0	0		2	0
7/22-28	SS	0*	352	1	0*		0*	0
	DS	5	1,821	4	0		1	0
7/29-8/4	SS	0	310	0	0		0	0
	DS	1	1,482	1	1*		1	1
8/5-11	SS	0	38	TS 20*	TS 16*		0	0
	DS	1	992				0	1
8/12-18	SS	0	196	1	1	0	0	0
	DS	1	97	2	1	1	0	3
8/19-25	SS	0	186	0	0	for August	0	0*
	DS	1	10	0	0		1	1
8/26-9/1	SS	0	141	0	1		0	0*
	DS	1	33	1	1		2	1*

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
9/2-8	SS	0	126	0	0		0	0
	DS	1	17	1	2		0	0
9/9-15	SS	0	177	1	1	0	0	0
	DS	0	774	4	2	1	0	0
						for September		
9/16-22	SS	0	270	2	3		0	0
	DS	1	2,198	9	10		0	1
9/23-29	SS	0	201	0	1		0	0
	DS	2	1,788	0	4		1	0
9/30-10/6	SS	0	204	1	1		0	0
	DS	0	1,767	5	2		2	0
10/7-13	SS	0	225	2	1		0	0
	DS	1	2,151	6	8		3	0
10/14-20	SS	1	42	1	1	0	0	0
	DS	2	590	2	3	1	1	0
						for October		

SS = suspended solids.

DS = dissolved solids.

Table 3 (Continued)

CONCENTRATIONS OF COBALT-60, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
10/21-27	SS	0*	10	2	0		0	0
	DS	0	1,087	3	2		1	1
10/28-11/3	SS	0	36	2	0		0	0
	DS	2	1,299	2	2		0	0
11/4-10	SS	0	13	2	0		0	0
	DS	1	2,123	8	4		2	1
11/11-17	SS	0	0	2	0	0	0	0*
	DS	0	1,603	14	11	1 for November	2*	0
11/18-24	SS	0*	227	3	1		0	0
	DS	1	1,981	15	15		2	1
11/25-12/1	SS	0	79	2	0		0*	0
	DS	2		6	3		0*	0

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Even the maximum concentrations of cobalt-60 found at all stations are far below MPC values. Consequently, mean concentrations were not computed.

The distribution of cobalt-60 activity between the suspended and dissolved solids in the samples is summarized in the following tabulation. Percentages are arithmetic averages of all samples. Median percentages are also indicated.

Distribution of Cobalt-60 in Water Samples

	Percent Total Activity in			
Station	Suspended Solids		Dissolved Solids	
	Mean	Median	Mean	Median
Clinch River at Oak Ridge water plant	5	0	95	100
White Oak Creek at White Oak Dam	19	12	81	88
Clinch River at Gallaher Bridge	27	25	73	75
Clinch River at Centers Ferry	30	25	70	75
Tennessee River at Watts Bar Dam	2	0	98	100
Tennessee River at Chickamauga Dam	3	0	97	100

These data indicate 70 to 98 percent of the total cobalt-60 present in the water phase is actually in solution. In White Oak Creek and in Clinch River, approximately 20 to 30 percent of the cobalt-60 present is associated with the suspended solids, but in the Tennessee River the percentage drops to only 2 or 3 percent. This would seem to indicate loss of sediment (and the associated activity) from the water phase in a downriver direction.

Mass Curves--Mass curves of cobalt-60 loads at all stations are shown in figure 9. The curves for White Oak Dam, Gallaher Bridge, and Centers Ferry plot reasonably close together throughout the period of record. Thus there seems to have been no significant loss of this radionuclide in Clinch River. Actually there was an apparent gain in load at Centers Ferry during January and February 1962. However, because of malfunctioning of the sampling equipment at the Centers Ferry station, the reported load at this station might be incorrect. If the curve value for December 1, 1961, is adjusted to about 22 curies (the value obtained by extending the curve established prior to about October 1), and the load thereafter accumulated from this value, the mass curve for this station would fall slightly below the curve for Gallaher Bridge.

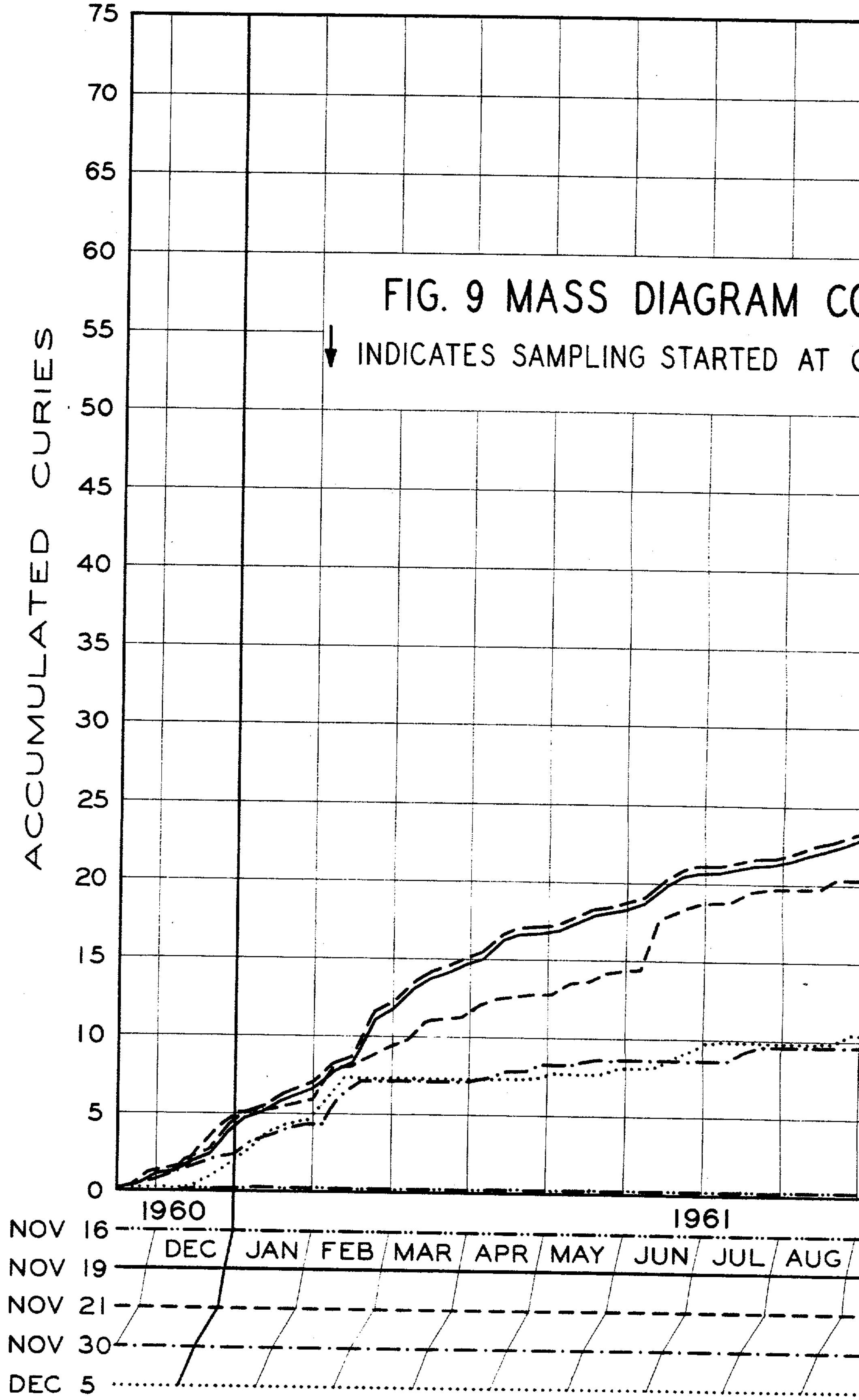
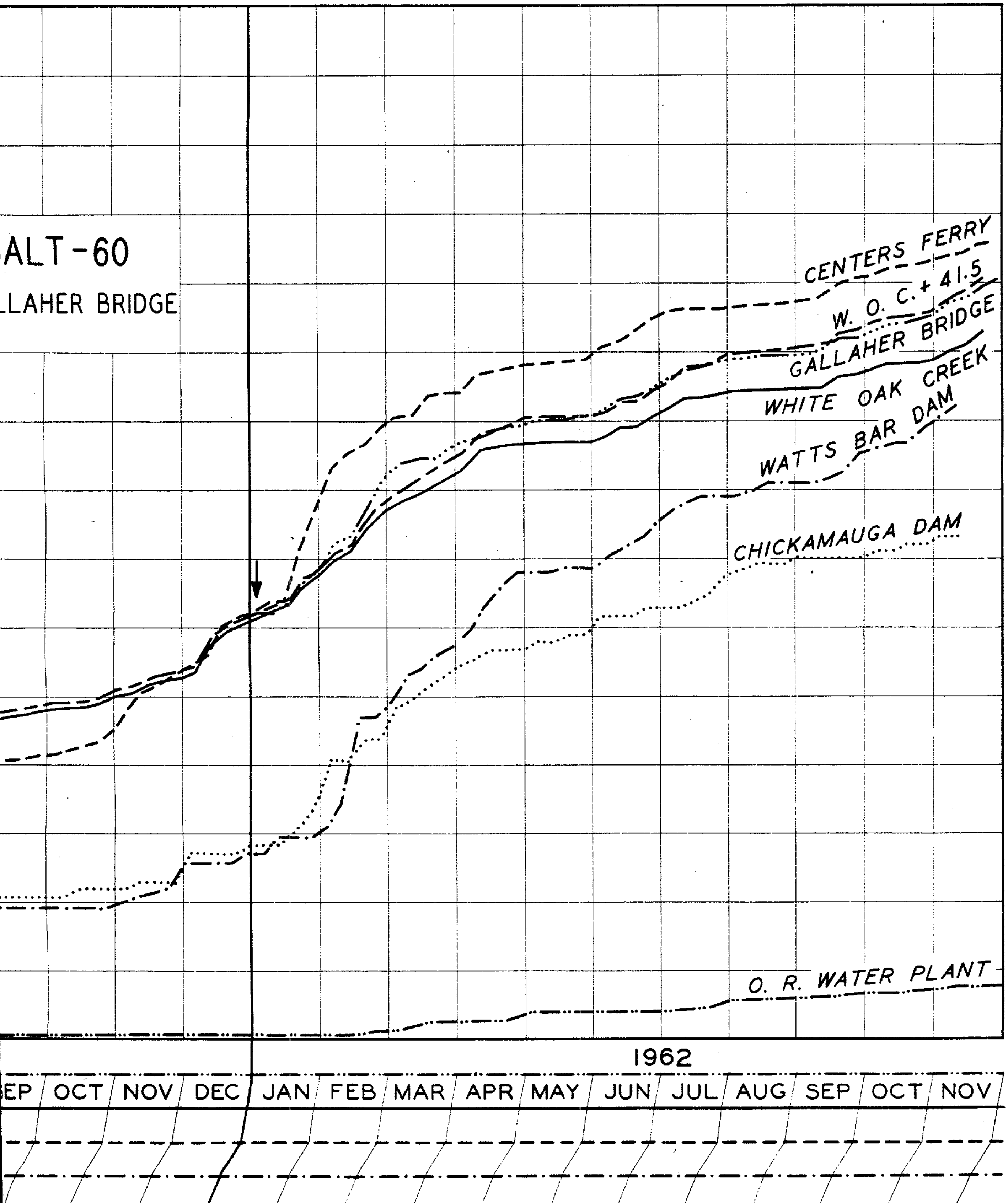


FIG. 9 MASS DIAGRAM CO
INDICATES SAMPLING STARTED AT C
ACCUMULATED CURIES
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1960
1961
NOV 16
NOV 19
NOV 21
NOV 30
DEC 5
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG



ALT-60
LLAHER BRIDGE
CENTERS FERRY
W. O. C. + 41.5
GALLAHER BRIDGE
WHITE OAK CREEK
WATTS BAR DAM
CHICKAMAUGA DAM
O. R. WATER PLANT
1962
EP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV

The total load for the two-year sampling period would be about 53 curies. The curves could then be interpreted as showing a very slight loss of cobalt-60 in Clinch River due to sedimentation.

Curves for both Watts Bar and Chickamauga Dams indicate a cumulative loss from the load measured at both White Oak Dam and at Centers Ferry. However, most of this loss is indicated to have occurred during the spring and summer of 1961. From November 1961 through November 1962, the curves for White Oak Creek and Chickamauga Dam are surprisingly parallel. Thus during this period the only effect discernible in the river system was dilution, since the load going in at White Oak Dam arrived later, undiminished, at Chattanooga.

Comparison with Load Measured by ORNL--The data for cobalt-60 plotted in figure 6 indicate serious disagreement in measured loads at White Oak Dam for many of the individual months, but over all the total load during the two-year period was found to be 46.31 curies by ORNL and 51.47 curies by the subcommittee. These values represent a difference of about 10 percent.

Ruthenium-106, Concentrations and Total Stream Loads

Concentrations of ruthenium-106 found in all samples for the period of available record at all stations are shown in table 4.

A factor not noted in earlier progress reports, which could affect reported concentrations to some extent, is the presence of ruthenium-103 (half life = 40 days) and possibly other fission products from weapons fallout, in the samples. Since the mean storage time of the samples prior to counting was approximately 60 to 80 days, measurable quantities of the ruthenium-103 could have been present if the samples contained relatively fresh fallout material. Unfortunately the age and quantities of fallout entering the river cannot be estimated from the available data. Any ruthenium-103 present in the samples would be reported as ruthenium-106 since the respective radionuclides are not distinguishable by the methods used in the study. However, the quantities of ruthenium-103 present are believed to be relatively insignificant in relation to the amounts of ruthenium-106 released via White Oak Creek.

Maximum concentrations found in the weekly (monthly at Loudon) composite samples (including both suspended and dissolved solids) are shown in the tabulation on page 66. Flow-weighted mean concentrations are also shown.

In only White Oak Creek do the maximum concentrations exceed MPC values for drinking water. Mean concentrations at all sampling stations except White Oak Creek at the dam, are far below MPC values for drinking water.

Table 4

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date	Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at		
					Loudon, Tenn.	Watts Bar Dam	Chickamauga Dam
1960							
11/13-19	TS 10	140,424		234			
11/20-26	TS 47	268,169		337			269
11/27-12/3	TS 2	252,368		772		62	38
12/4-10	TS 223	184,714		187		51	74
12/11-17	TS 16	244,604		683	3	77	152
					for December		
12/18-24	TS 2	192,009		845		59	73
12/25-31	TS 218	217,883		812		117	61
1961							
1/1-7	TS 4	141,791		1,434		96	86
1/8-14	TS 1	171,891		123		174	62
1/15-21	TS 3	294,412		415	0	168	133
1/22-28	TS 1	188,843		384	for January	90	117
1/29-2/4	TS 10	218,938		189		121	88
2/5-11	TS 2	292,517		2,480		100*	97
2/12-18	TS 5	208,479		2,633	2	55	76
2/19-25	TS 7	145,070		415*	for February	112	46
2/26-3/4	TS 10*	87,955		384		192	144
3/5-11	TS 11	98,092		406		91	82
3/12-18	TS 3	125,074		312	SS 0	165	64
3/19-25	TS 2	157,283		347	DS 49	77	38
3/26-4/1	TS 0	144,464		222	for March	66	46

*Value is estimated.

Blank spaces indicate data not available.

TS = total solids; SS = suspended solids; DS = dissolved solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
4/2-8	TS	13	119,620		1,344		61	52
4/9-15	TS	13	106,627		548		56	42
4/16-22	TS	8	121,368		1,263	SS 0	106	38
4/23-29	SS	0*	8,781		117	DS 62	TS 131	TS 46
	DS	123	108,972		260*	for April		
4/30-5/6	SS	14	13,657		39		2	1
	DS	32	15,769		195		84	74
5/7-13	SS	0	9,981		56		2	2
	DS	14	187,918		704		119	30
5/14-20	SS	9*	2,909		32	0	2	8
	DS	20	173,094		392	6	83	107
5/21-27	SS	2	11,004		115	for May	2	5
	DS	6	74,265		523		70	110*
5/28-6/3	SS	1	8,389		91		1	0
	DS	27	76,363		220		83	121
6/4-10	SS	4	76,650*		42		6	4
	DS	12	159,271		215		91	54
6/11-17	SS	3	11,899		219	0	0	2
	DS	11	145,841		646	19	87	61
						for June		

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
6/18-24	SS	4	4,789		304		1	2
	DS	29	123,519		1,154		67	56
6/25-7/1	SS	2	3,386		230		0	1
	DS	7	55,609		740		55	36
7/2-8	SS	24	3,063		3		10	3
	DS	60	67,066		8		120	80
7/9-15	SS	0	3,013		19	1	3	3
	DS	3	88,547		58	3 for July	95	59
7/16-22	SS	0	5,841		50		1	3
	DS	7	68,000*		475		64	59
7/23-29	SS	2	1,966		38		3	2
	DS	169	54,769		190		55	29
7/30-8/5	SS	0	3,680		0		6	0
	DS	16	104,740		185		41	36
8/6-12	SS	1	4,756		0		0	0
	DS	0	153,758		148		25	45
8/13-19	SS	1	4,411		0	1	0	0
	DS	185	75,093		5	2 for August	84	18

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
8/20-26	SS	1	5,615		13		0	0
	DS	3	90,162		385		20	6
8/27-9/2	SS	9	2,030		7		2	2
	DS	1	180,500*		128		26	39
9/3-9	SS	1	TS 197,800*		2		3	1*
	DS	7			10		41	19
9/10-16	SS	1	TS 154,600*		4	1	1	1
	DS	4			7	64 for September	23	33
9/17-23	SS	5	TS 159,750*		5		2	2
	DS	19			6		13	14
9/24-30	SS	1	TS 125,950*		26		0	2
	DS	1			6		7	8*
10/1-7	SS	2	1,331		21		0	1
	DS	5	62,173		26		0	4
10/8-14	SS	1	570		115		2	1
	DS	2	52,204		155		6	3
10/15-21	SS	1	1,076		51	0	1	2
	DS	4	128,700*		42	8 for October	3	1

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1961		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
10/22-28	SS	-1	224,100*		27		1	2
	DS	3	21,361		18		17	8
10/29-11/4	SS	2	5,704		58		0	1
	DS	0	209,186		324		10	16
11/5-11	SS	1	1,536		390		TS 5	TS 9
	DS	129	238,627		292			
11/12-18	SS	1	8,313		367	2	1	TS 88
	DS	8	282,698		212	145*	75	
11/19-25	SS	4	2,544		135*	for November	TS 60*	TS 85
	DS	12	199,997		424			
11/26-12/2	SS	4	3,478		320		3	6
	DS	7	138,438		183		54	32
12/3-9	SS	4	3,356		38		6	3
	DS	8	225,385		620		63	42
12/10-16	SS	8	4,576		37	4	0	2
	DS	60	134,500		805	292	73	53
12/17-23	SS	11	1,685		24	for December	5	4
	DS	30	52,830		975		125	80
12/24-30	SS	5	1,298		23		3	6
	DS	24	114,025		404		39	69

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
12/31-1/6	SS	4	1,707		13		14	5
	DS	38	128,816		353		45	33
1/7-13	SS	9	1,913	12	13		6	3
	DS	75	120,000*	182	399		83	53
1/14-20	SS	5	1,585	50	12	8	8	2
	DS	71	108,171	719	376	2	136	210
						for January		
1/21-27	SS	7	3,890	37	24		3	1
	DS	50	103,473	512	542		81	90
1/28-2/3	SS	9	3,026	29	TS 235*		5	5
	DS	3	70,115	213			81	55
2/4-10	SS	6	1,955	21	TS 200*		4	6
	DS	-1	94,595	138			21	42
2/11-17	SS	8	1,960	18	24	8	7	4
	DS	1	93,361	130	121	5	18*	40*
						for February		
2/18-24	SS	24	3,772	52	23		7	8
	DS	8	85,337	482	289		50	53
2/25-3/3	SS	27	2,110	34	20		10	3
	DS	-23	54,187	273	189		104	53

*Value is estimated.

Blank spaces indicate data not available.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
3/4-10	SS	10	2,270	17	21		4	3
	DS	6	79,094	127	60		26	30
3/11-17	SS	11	TS 87,600*	18	10	4	7	4*
	DS	3		73	58	64	57	88
3/18-24	SS	15	3,298	18	25	for March	10*	4
	DS	4	44,402	80	171		25	33
3/25-31	SS	10	1,259	52	13		13	6
	DS	-1	85,423	238	174		52	23
4/1-7	SS	12	1,772	14	41		9	9
	DS	9	81,578	635	97		30	33
4/8-14	SS	31	3,320	86	64		6	12*
	DS	34	72,501	200*	680		41	32
4/15-21	SS	6	1,971	78	42	1	6	7
	DS	-3	52,418	284	376	32	75	47
4/22-28	SS	5	1,698	24	16	for April	15	7
	DS	27	62,902	87	78		51	61
4/29-5/5	SS	4	1,700*	13	11		1	5
	DS	41	81,897	66	40		65	41

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
5/6-12	SS	3	1,900	22	11		3	5
	DS	-2	40,756	53	36		26	22
5/13-19	SS	4	882	17	13	1	2	3
	DS	3	13,735	22	45	2	33	4
5/20-26	SS	4	817	12	10	for May	4	1
	DS	4*	36,860	27	14		18	8
5/27-6/2	SS	TS 5*	2,153	17	12		2	4
	DS		23,237	23	14		9	11
6/3-9	SS	3	7,850	31	53		4	5
	DS	-1	108,784	140	276		11	9
6/10-16	SS	5	8,553	52	42	5	0	0
	DS	2	132,388	215	342	8	7	4
6/17-23	SS	7	3,982	39	320*	for June	1	1
	DS	-1	56,020	72	148		7	1
6/24-30	SS	4	17,146	69	110		1	2
	DS	-1	46,056	204	247		16	12

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
7/1-7	SS	1	13,168	83	TS 250*		2	4
	DS	-1	64,164	170*			21	16
7/8-14	SS	3	6,397	88	TS 225*		3	1
	DS	0	92,971	223			21	13
7/15-21	SS	2	790	25	130*	2	5	1
	DS	3	3,260	32	15	3	30	18
7/22-28	SS	0*	3,538	22	100*	for July	2*	1
	DS	15	91,380	118	28		25	15
7/29-8/4	SS	3	3,714	9	TS 80*		2	3
	DS	8	74,957	78			17	33
8/5-11	SS	5	1,811	TS 98*	TS 65*		2	3
	DS	5	46,233				13	28
8/12-18	SS	2	665	17	24	0	4	1
	DS	4	3,111	65	-5	4	-5	19
8/19-25	SS	4	1,105	6	4	for August	1	0*
	DS	9	1,206	4	14		18	18

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
8/26-9/1	SS	2	350	3	3		2	0*
	DS	7	1,107	4	8		8	7*
9/2-8	SS	4	338	5	5		1	0
	DS	0	1,127	21	5		0	1
9/9-15	SS	3	1,800	11	9	1	1	2
	DS	-1	34,130	91	54	6	12	2
						for September		
9/16-22	SS	4	3,740	39	70		1	1
	DS	21	89,381	363	436		11	0
9/23-29	SS	4	1,870	8	10		2	1
	DS	3	77,720	101	136		8	8
9/30-10/6	SS	4	2,798	21	17		3	1
	DS	13	61,193	168	103		33	0
10/7-13	SS	4	2,644	27	30	0	4	5
	DS	6	72,965	197	298	3	22	4
						for October		

*Value is estimated.

SS = suspended solids.

DS = dissolved solids.

Table 4 (Continued)

CONCENTRATIONS OF RUTHENIUM-106, pc per liter

Date 1962		Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River at Gallaher Bridge	Clinch R. above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
10/14-20	SS	12	524	23	20		4	2
	DS	5	22,192	38	75		25	21
10/21-27	SS	4*	440	20	7		2	4
	DS	11	38,291	53	41		75	32
10/28-11/3	SS	0	940	25	7		1	2
	DS	8	49,971	46	63		23	23
11/4-10	SS	6	1,058	47	11	5	6	3
	DS	2	73,832	247	155	6 for November	15	11
11/11-17	SS	10	417	74	20		2	2*
	DS	7	60,470	462	391		23*	5
11/18-24	SS	0*	4,035	57	24		3	2
	DS	17	67,577	655	686		25	6
11/25-12/1	SS	6	1,388	43	13		TS 30*	4
	DS	7		149	129			26

*Value is estimated.

SS = suspended solids; DS = dissolved solids; TS = total solids.

Maximum and Mean Concentrations of Ruthenium-106

Station	Highest Concentration pc per liter	Period of Occurrence	Flow-Weighted Mean Concentration pc per liter
Clinch R. at Oak Ridge water plant	223	Dec. 4-10, 1960	23
White Oak Creek at White Oak Dam	294,412	Jan. 15-21, 1961	109,800
Clinch R. at Gallaher Bridge	769	Jan. 14-20, 1962	345*
Clinch R. at Centers Ferry	2,633	Feb. 12-18, 1961	317
Tenn. R. at Loudon, Tenn.	296	December 1961	**
Tenn. R. at Watts Bar Dam	192	Feb. 26-Mar. 4, 1961	63
Tenn. R. at Chickamauga Dam	269	Nov. 20-26, 1960	51

*Record begun January 8, 1962.

**Not applicable.

The distribution of ruthenium-106 activity between the suspended and dissolved solids in the samples is summarized in the following tabulation. Percentages are arithmetic averages of all samples. Median percentages are also indicated.

Distribution of Ruthenium-106 in Water Samples

Station	Percent Total Activity in Suspended Solids		Percent Total Activity in Dissolved Solids	
	Mean	Median	Mean	Median
Clinch River at Oak Ridge water plant	44	29	56	71
White Oak Creek at White Oak Dam	6	4	94	96
Clinch River at Gallaher Bridge	21	17	79	83
Clinch River at Centers Ferry	21	16	79	84
Tennessee River at Watts Bar Dam	11	7	89	93
Tennessee River at Chickamauga Dam	15	8	85	92

From these data it is apparent that from 79 to 94 percent of the ruthenium-106 activity is associated with the dissolved solids, or in other words, dissolved in the water itself. Neither the time of contact with the suspended solids, nor sedimentation, appear to have any significant influence on the distribution of activity between suspended solids and dissolved solids since the percentage associated with the dissolved solids decreases from 94 percent at White Oak Dam to 79 percent at Centers Ferry, then goes back up to 89 percent at Watts Bar, and back down to 85 percent at Chickamauga Dam.

Mass Curves--Cumulative curves of ruthenium-106 loads at all stations except Loudon are shown in figure 10.

During the first year of sampling, the mass curves for all stations below White Oak Creek agree quite closely with that for White Oak Creek; then, beginning in the fall of 1961 and continuing through March 1962, the downriver curves diverge to some extent. From March through November 1962, the curves remain essentially parallel to each other. The divergence in early 1962 appears to reflect the effect of fallout from weapons testing. (See figure 5, page 23.)

Throughout the two-year period the curve for Centers Ferry is practically identical to the one for White Oak Creek. Likewise, during the last 11 months of record the curve for White Oak Creek plus the Oak Ridge water plant is nearly identical to that for Gallaher Bridge. Throughout the entire period of record, the curves for Watts Bar Dam and Chickamauga Dam are essentially the same.

Based on the rather amazing agreement between the cumulative loads measured at all stations below White Oak Dam with the load measured at White Oak Dam, it can be definitely concluded that during the two-year sampling period essentially all the ruthenium-106 discharged from Oak Ridge passed through the river system to Chattanooga in the water phase. That ruthenium-106 which is found in bottom sediments between Oak Ridge and Chattanooga must represent the continued accumulation over the years of a very small percentage of the annual load discharged at Oak Ridge.

The good agreement in the cumulative loads measured at the successive stations indicates considerable confidence can be placed in the methods used throughout the study in sampling and compositing.

Comparison with Loads Measured by ORNL--As with the other radionuclides, comparison of monthly loads at White Oak Dam as measured by the subcommittee and by ORNL, indicates several rather serious disagreements, as shown in figure 7, page 25. However, comparison of cumulative loads measured over longer periods indicates better agreement, as might be expected.

The first 12-month period (December 1960 through November 1961) shows a total discharge of about 1,900 curies of ruthenium-106 at White Oak Dam as measured by the subcommittee, while the second 12-month period

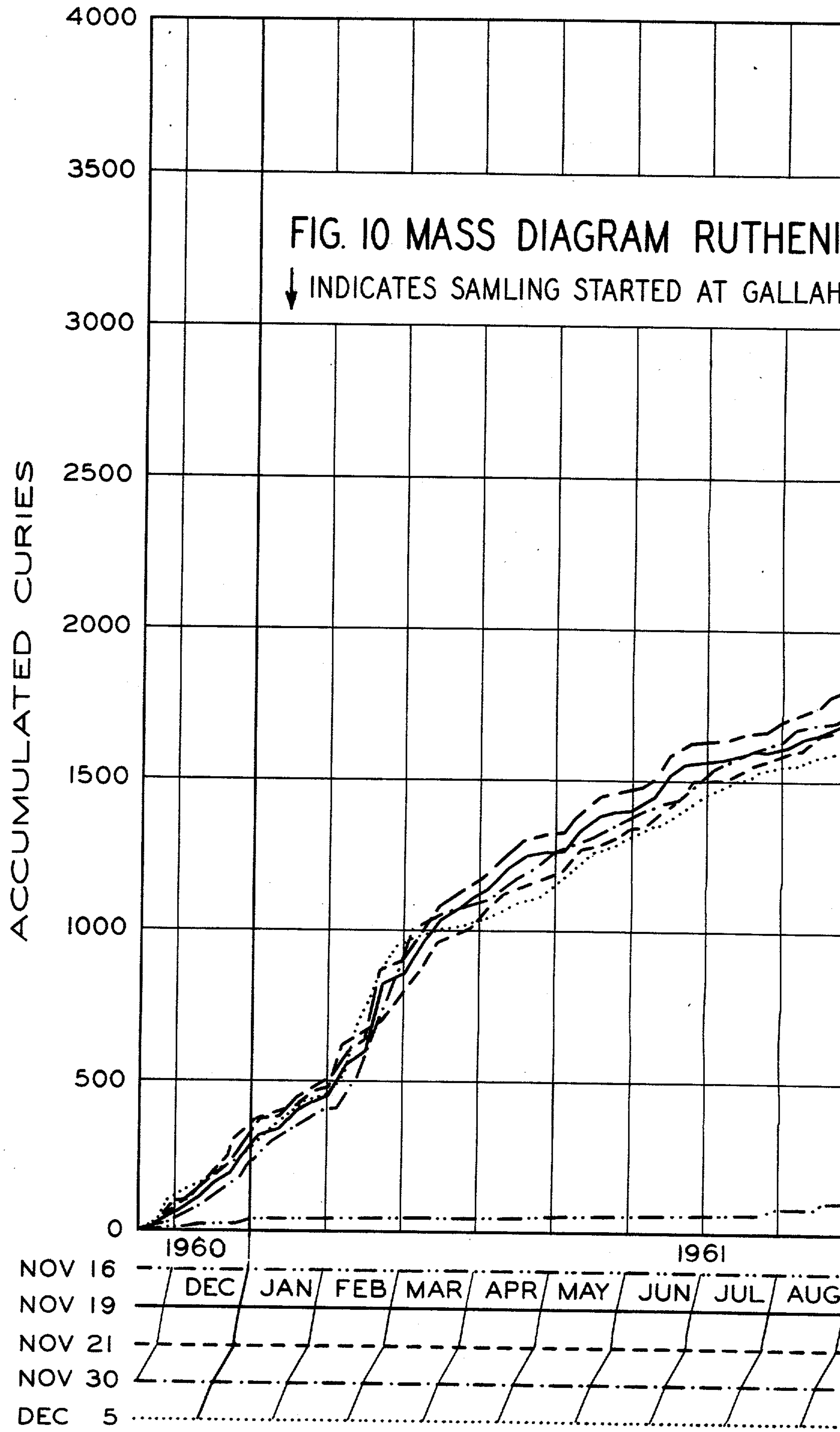
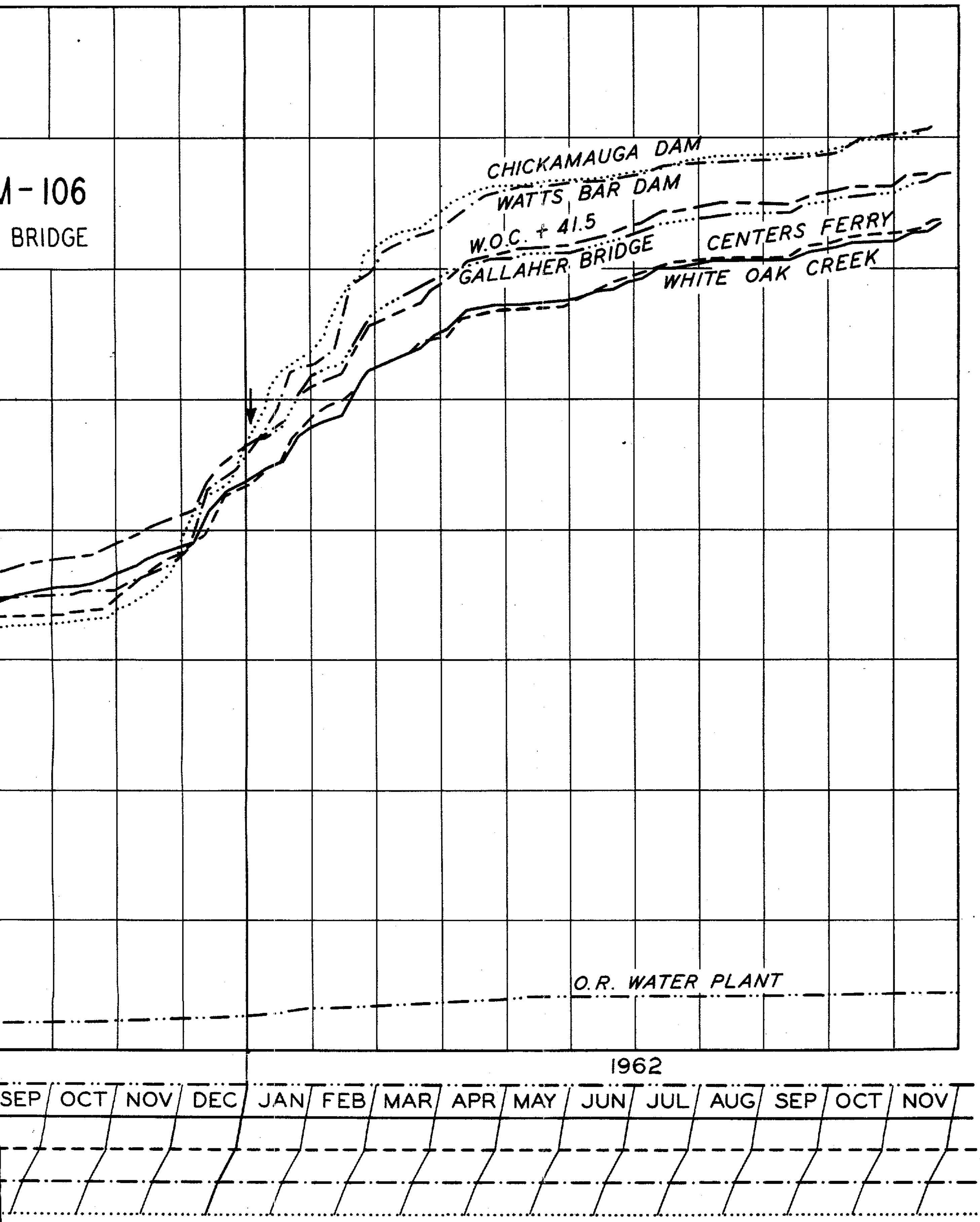


FIG. 10 MASS DIAGRAM RUTHENI

↓ INDICATES SAMLING STARTED AT GALLAH


M-106
BRIDGE
CHICKAMAUGA DAM
WATTS BAR DAM
W.O.C. + 41.5
GALLAHER BRIDGE
CENTERS FERRY
WHITE OAK CREEK
O.R. WATER PLANT
1962
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV

(December 1961 through November 1962) shows a total discharge of about 1,300 curies. Data supplied by the Oak Ridge National Laboratory show a total discharge of 1,906 curies at White Oak Dam during the first 12-month period and a total discharge of 1,586 curies for the second 12-month period. Thus in comparing the total loads reported in this study with those reported by ORNL, the total loads for the first 12-month period are found to be identical. On the other hand, the difference of nearly 300 curies during the last 12-month period represents a disagreement of approximately 22 percent. If the White Oak Creek load for the last 12 months of record as measured by the subcommittee, were increased by 300 curies, it would equal almost exactly that measured for Chickamauga Dam. This probably indicates a negative bias in the White Oak Creek values reported by the subcommittee for the last 12-month period. (See figure 10, page 68.)

Effects of Operation of Melton Hill Dam on Dispersion of Radionuclides

The operation of Melton Hill Dam at mile 23.1 on Clinch River will change the hydraulic pattern of releases of radioactive waters from White Oak Creek into Clinch River. The potential effects of this altered hydraulic pattern on the dispersion of radioactive waters originating at the Oak Ridge National Laboratory have been investigated cooperatively in the field by personnel of the U. S. Geological Survey and of the Oak Ridge National Laboratory.

From results of these dispersion studies that have been and are being reported separately, the subcommittee concludes that although the time versus concentration pattern of radionuclides will be altered drastically in the Clinch River embayment of Watts Bar Reservoir, the pattern of dispersion in the Tennessee River will not be altered sufficiently from that observed during the two-year study reported here to justify reactivation of the network of sampling stations.

Recommendations

Recommendations 1, 2, and 3 concern the monitoring program which the subcommittee feels must be continued indefinitely at and below Oak Ridge. Recommendations 4, 5, and 6 concern improvements that should be made in studies of the type reported here, should such a study be reinitiated in the future at and below Oak Ridge, or put into operation by others at some other location for similar purposes.

1. (a) Continuous monitoring and proportional sampling should be continued at White Oak Dam, and weekly composite samples should be examined for concentrations of strontium-90, cesium-137, cobalt-60, and ruthenium-106. Arrangements should be made to keep this station rated since knowledge of continuous streamflow rates at this station is essential.

(b) Proportional sampling should be initiated very soon and continued indefinitely on the power discharge of Melton Hill Dam. Weekly composite samples should be examined for radionuclide activity.

(c) Proportional sampling should be initiated very soon and continued indefinitely at or near the present location of the water intake in Clinch River of the Oak Ridge Gaseous Diffusion Plant. Volumes of river water, proportioned to the instantaneous rate of river discharge at the intake site, should be added to the composite sample at intervals of not more than 15 minutes. Such samples, composited weekly, should be examined for the radionuclides of importance unless sample results at White Oak Dam, or at Melton Hill Dam, indicate need for more frequent examination.

(d) If at any time in the future it becomes reasonably possible for any significant load of radionuclides to enter Clinch River downstream from the monitoring station at the water intake of the Oak Ridge Gaseous Diffusion Plant, either the station should be moved far enough downstream to intercept such additional inflow, or an additional downstream monitoring station should be established.

2. Since the Oak Ridge National Laboratory and the Public Health Service will both be monitoring Clinch River below White Oak Creek, these two agencies, and any others that may collect radiological samples here, should compare results obtained on regularly scheduled split samples. This is essential to prevent differences in technique, equipment, etc., from introducing disagreement in routine sampling results.

3. The Public Health Service should be supplied with part of each weekly composite sample collected at the water intake of the Oak Ridge Gaseous Diffusion Plant. The Public Health Service should be requested in a letter from the Chairman of the Clinch River Study Steering Committee, to utilize these samples in the radiological determinations made on water samples collected at this station in its Water Pollution Surveillance System.

4. If any detailed study of this nature is made in the future, it would be extremely helpful in determining cesium-137 activity levels if this radionuclide were extracted from the sample by the best chemical separation technique available, prior to counting. In any situation where the gamma spectrum of a radionuclide of importance is seriously masked by some other radionuclide, chemical separation, as well as gamma spectrometry, should be used. The most sensitive, yet accurate, technique and

equipment available should be applied to the determination of the concentration of each radionuclide. It would be helpful if a few "dry runs" were made at all proposed sampling stations prior to the initiation of routine sampling, to determine the volumes of samples needed at the various stations to provide sufficient activity, after concentration, for accurate measurements.

5. It is recommended for any future study of this nature that the actual, and relative concentrations of radionuclides in the suspended and dissolved solids be determined as carefully as possible in a limited number of special samples collected at such times as would permit detection of the influences, if any, on relative concentrations, of such factors as water chemistry, streamflows, particle sizes, time of flow below Oak Ridge, water temperature, and possibly other variables. To provide needed information on precision and reproducibility of results, more effort than in the present study should be directed toward duplicate processing of "whole samples," and in processing duplicate samples (twice the needed volume, mixed and split).

6. If a network of sampling stations is needed for future studies of this general nature, a companion network of precipitation stations would be desirable to provide information on the fallout contribution to the radionuclide load.

Respectfully submitted,

SUBCOMMITTEE ON WATER SAMPLING AND ANALYSIS

M A Churchill

M. A. Churchill, Chairman
J. S. Cragwall
S. L. Jones
Dr. Conrad P. Straub